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Popular Mechanics

**How to drive when
it's too icy to walk**

**WINTER POWER-OUTS:
Low-cost ways to be snug and safe**

PM drives the 5-cylinder Audi



SPECIAL

**19 easy-to-make
Christmas gifts
COMPLETE PLANS**

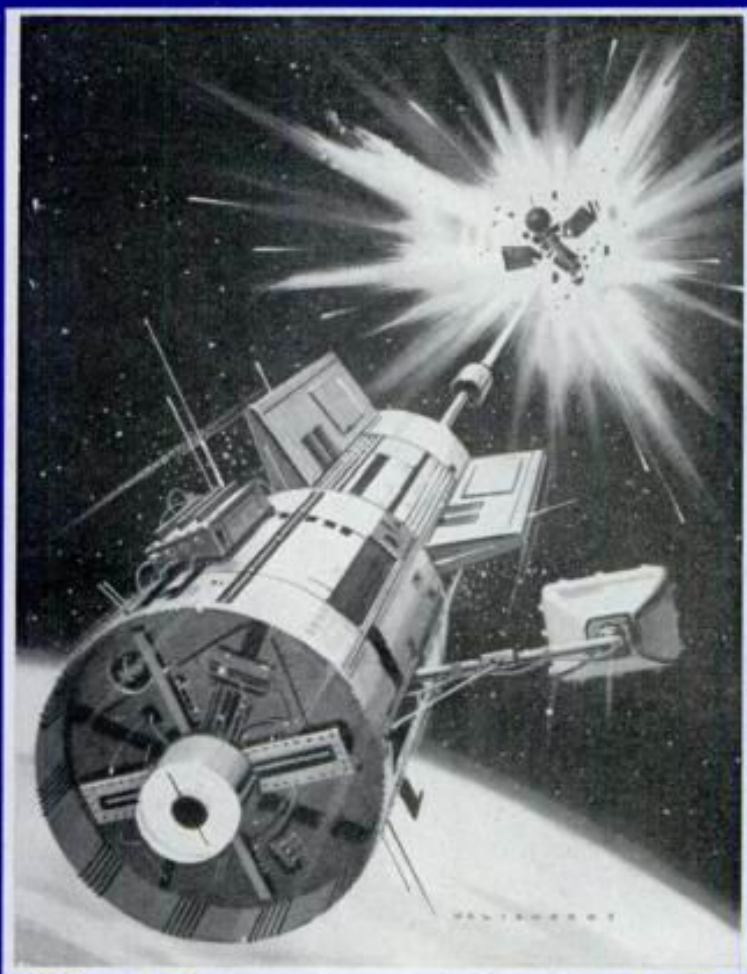


**NEW SUPER CBs:
13 rigs that give you
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**PLUS: Upholstering
■ VW Microbus Owners
Report ■ 3-wheel cars**

**MAKING A COMEBACK?
SUPER FLYING BOATS**

**...with the real story behind
Howard Hughes and his
'Spruce Goose'**



Will the next war be fought in space?

by Edward Hymoff

A hunter-killer satellite silently stalks another satellite in space. Slowly closing on its prey, it blasts it out of orbit. An early-warning satellite is "blinded" by the brilliant flash of a laser beam. Unable to "see," it fails to detect the oncoming barrage of ballistic missiles—in an instant its country is destroyed. A space Shuttle suddenly appears from nowhere, grabs an enemy satellite in its mechanical claws and pulls it into its cavernous cargo bay—like a giant man-eating insect. Trapped,



1200 passengers on three decks... a comeback for

by Paul Wahl

On Oct. 23, 1945, an American Export Airlines Douglas DC-4 took off on the inaugural flight of commercial land-plane service between New York and London. The era of the transoceanic flying boat had ended. Now, a generation later, its comeback is planned by a Japanese firm that has a 1200-passenger, 1.04-million-pound, giant seaplane on the drawing board.

The proposed craft is called Shin Meiwa GS (for "Giant Seaplane") and will dwarf all of today's largest airplanes including the Boeing 747 and Lockheed C-5A. Only in its wingspan, 255.9 feet, is the GS smaller than Howard Hughes's famed "Spruce Goose." Overall, the 522-ton aircraft will be 293.9 feet long and 71.3 feet high; the extra-wide, rectangu-

lar hull will have a beam of 27.6 feet.

With 10-abreast seating, the 747 accommodates a maximum of 500 passengers. The triple-decked GS will carry 344 persons on its upper deck, 626 on the main deck and 230 on the lower deck, to reach the 1200 total. Payload is estimated at 120 tons.

Designed for transoceanic service, the GS will have a range of 3500 nautical miles. At an altitude of 37,000 feet, the cruising speed will be 486 knots. The plane will take off in 3084 feet at 92 knots and land in 1903 feet at 102 knots. It will operate in Sea State 3 (maximum wave height of 5 feet).

Six advanced, high-bypass-ratio turbofans of about 77,000 pounds thrust will be needed to power this mammoth flying boat. For enhanced STOL capability, the engines will jet exhaust air over the wing's upper surface in a propulsive lift

concept, similar to that of the Boeing YC-14. To that end, the engines will be mounted above and forward of the supercritical wing. An added advantage of this arrangement is that the engines are out of spray range and thus safe from danger of flameout due to excessive water ingestion.

Designers estimate that the state-of-the-art advances required by the Shin Meiwa GS—advanced turbofans, improved hull and supercritical wing designs, composite materials for weight savings and saltwater-corrosion resistance, water evacuation systems and the like—might take a half-dozen or so years to achieve. In today's yen, this flying boat would be priced at the equivalent of some \$60 million.

Impetus for bringing back the long-range flying boat is the current high price of real estate, particularly in Japan.



Flying firefighter boat Shin Meiwa PS-1 by the same company is now in production.

flying boats?

Cost of land-bound airports has soared and this means higher landing fees and increased passenger fares. Docking and terminal facilities for flying boat operations would be significantly less expensive. A seaplane base with the same traffic capacity might cost 25 percent less than the estimated \$3-billion price of the new international airport proposed for Osaka. The lower cost of facilities and the plane's great payload accommodation are expected to make the Shin Meiwa GS economically feasible—despite the flying boat's higher unit and operating costs compared with conventional airliners.

Shin Meiwa Industry Co. of Kobe is now the world's only builder of larger seaplanes. Similar four-turboprop STOL aircraft, the Shin Meiwa SS-2 antisubmarine patrol flying boat and SS-2A amphibian are in service with the Japan

Maritime Self-Defense Force, as is the US-1 search and rescue amphibian. A firefighting water bomber, based on the same design, has been developed for the National Fire Agency.

The Giant Seaplane is one of four flying boat concepts presently under study by Shin Meiwa. Others include a Light Amphibian (LA), Medium Amphibian (MA) and Medium Seaplane (MS). All will have shoulder-mounted engines for upper surface blowing and all but the LA will have supercritical wings.

Probably the first of these to be built will be the LA, since it's within the state of the art. A twin-turboprop, 40-passenger aircraft, the LA is intended primarily for island-hopping feeder-line service. Model MA, a medium-sized amphibian, powered by four turboprops, would carry 400 people on two decks. A scaled-down four-turboprop version of the GS, called MS,

will accommodate 300 travelers. While not amphibious in take-off and landing, the latter will be equipped with beaching gear for moving in and out of the water.

Although few flying boats have been built during the past 30 years, several hundred—mostly of World War II vintage—are still in regular service worldwide, doing jobs that other aircraft cannot handle as effectively. They fly search and rescue missions, do naval patrol duty, fight fires as water bombers, haul both passengers and freight where land planes can't go. Now quite ancient, many of these flying boats are fast approaching retirement. Just replacing them should add up to a good market for Shin Meiwa.

As for the Giant Seaplane: It may seem like a far-out idea, but it just might be the jumbo jet of the 1990s. If so, the spaciousness of the vast hull could permit a revival of luxury travel long gone.

space war

EARLY WARNING SATELLITE IS "BLINDED" BY LASER BEAM FROM EARTH OR OTHER SATELLITE

"MINE LAYER" SATELLITE SOWS PATH OF ONCOMING ENEMY SATELLITE WITH EXPLOSIVES

ENEMY SATELLITE FLIES INTO MINE FIELD, IS DESTROYED

SELF-DESTRUCT "SACRIFICIAL" SATELLITE RAMS ENEMY SATELLITE, BLOWS UP BOTH

the enemy satellite is a doomed "prisoner" captured far out in space, no longer able to detect or attack opposing spacecraft. And so the satellite "dogfight" continues—one zaps another, then it, in turn, is itself zapped out of the sky, a molten mass of blazing wreckage spinning crazily out of orbit to a fiery death in the atmosphere above us.

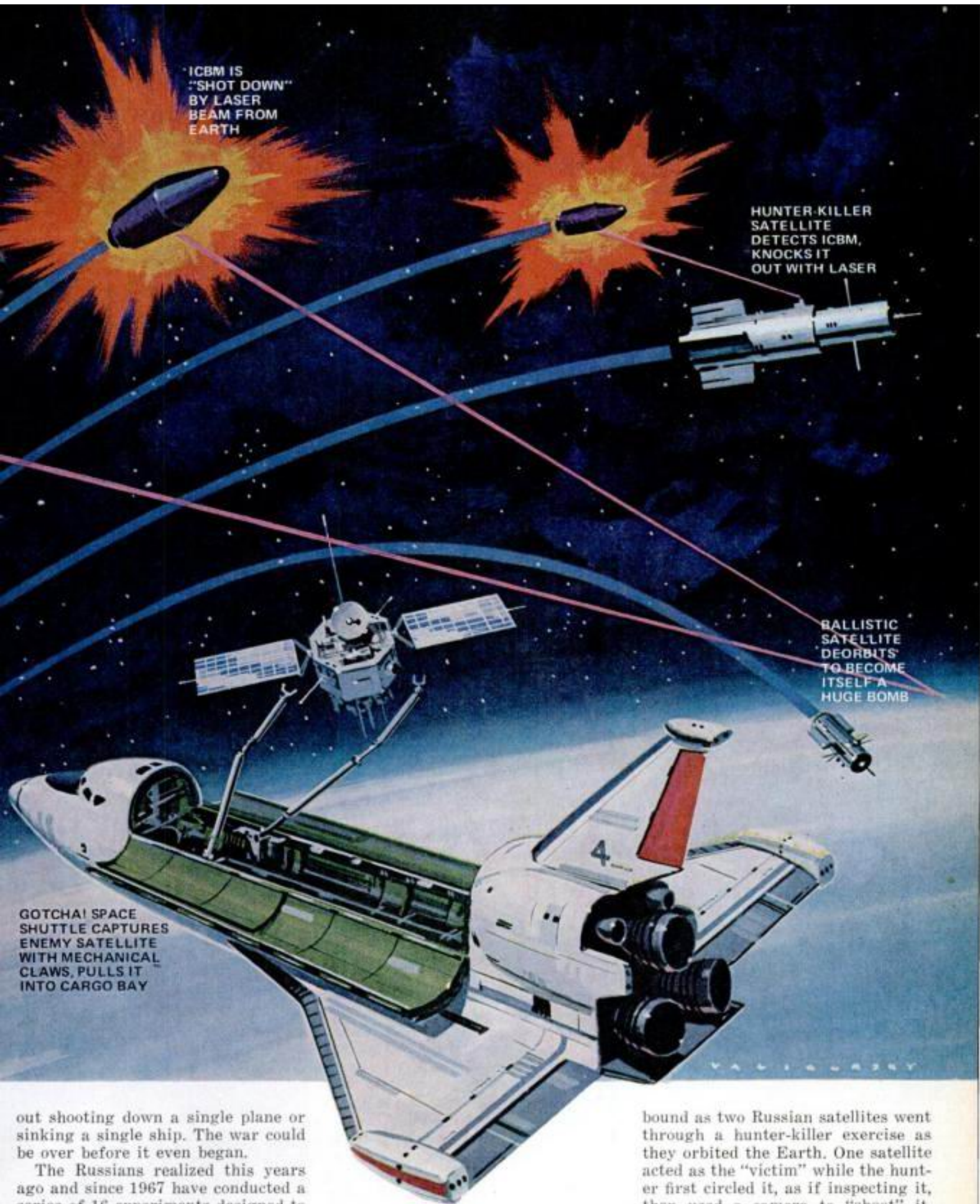
Science fiction? No, these are not scenes from a Buck Rogers or Flash Gordon comic strip. They are just a

few of the many very real and possible techniques that could be used in a future global war—a weird and eerie conflict fought thousands of miles out in space. The technology exists today; the capability is not far away.

Why should anyone want to shoot down satellites? Because, quite simply, they are our "eyes" in the sky. In today's modern sophisticated art of warfare, highly sensitive early-warning satellites have become our first line of defense—just as our now

largely obsolete DEW line used to be. Especially for the superpower nations that rely on them, satellites form a vital part of long-range detection, communication, navigation and missile-guidance systems that would be useless without them.

Eventually, "armed" satellites could be used as attack weapons as well as defensive aids. Any nation able to knock out another nation's satellites could, in effect, cripple all its enemy's forces in minutes with-



ICBM IS
"SHOT DOWN"
BY LASER
BEAM FROM
EARTH

HUNTER-KILLER
SATELLITE
DETECTS ICBM,
KNOCKS IT
OUT WITH LASER

BALLISTIC
SATELLITE
DEORBITS
TO BECOME
ITSELF A
HUGE BOMB

GOTCHA! SPACE
SHUTTLE CAPTURES
ENEMY SATELLITE
WITH MECHANICAL
CLAWS, PULLS IT
INTO CARGO BAY

out shooting down a single plane or sinking a single ship. The war could be over before it even began.

The Russians realized this years ago and since 1967 have conducted a series of 16 experiments designed to develop a special breed of hunter-killer satellite whose sole purpose is to blast unwanted foreign satellites into oblivion. This intriguing—and frightening—prospect took on a new and even more compelling importance when the mainland Chinese started

launching experimental spy satellites of their own in February 1976. The Soviet spy-in-the-sky developments stepped up in pace dramatically.

Last December, radar observers with the North American Defense Command (NORAD) watched spell-

bound as two Russian satellites went through a hunter-killer exercise as they orbited the Earth. One satellite acted as the "victim" while the hunter first circled it, as if inspecting it, then used a camera to "shoot" it, experts believe. The implication was grimly clear: If you can maneuver one satellite close enough to another to take its picture, you can also maneuver close enough to blow it up.

It is well known that most satellites already carry self-destruct ex-

'For all her luxury, she's still a riverboat.'

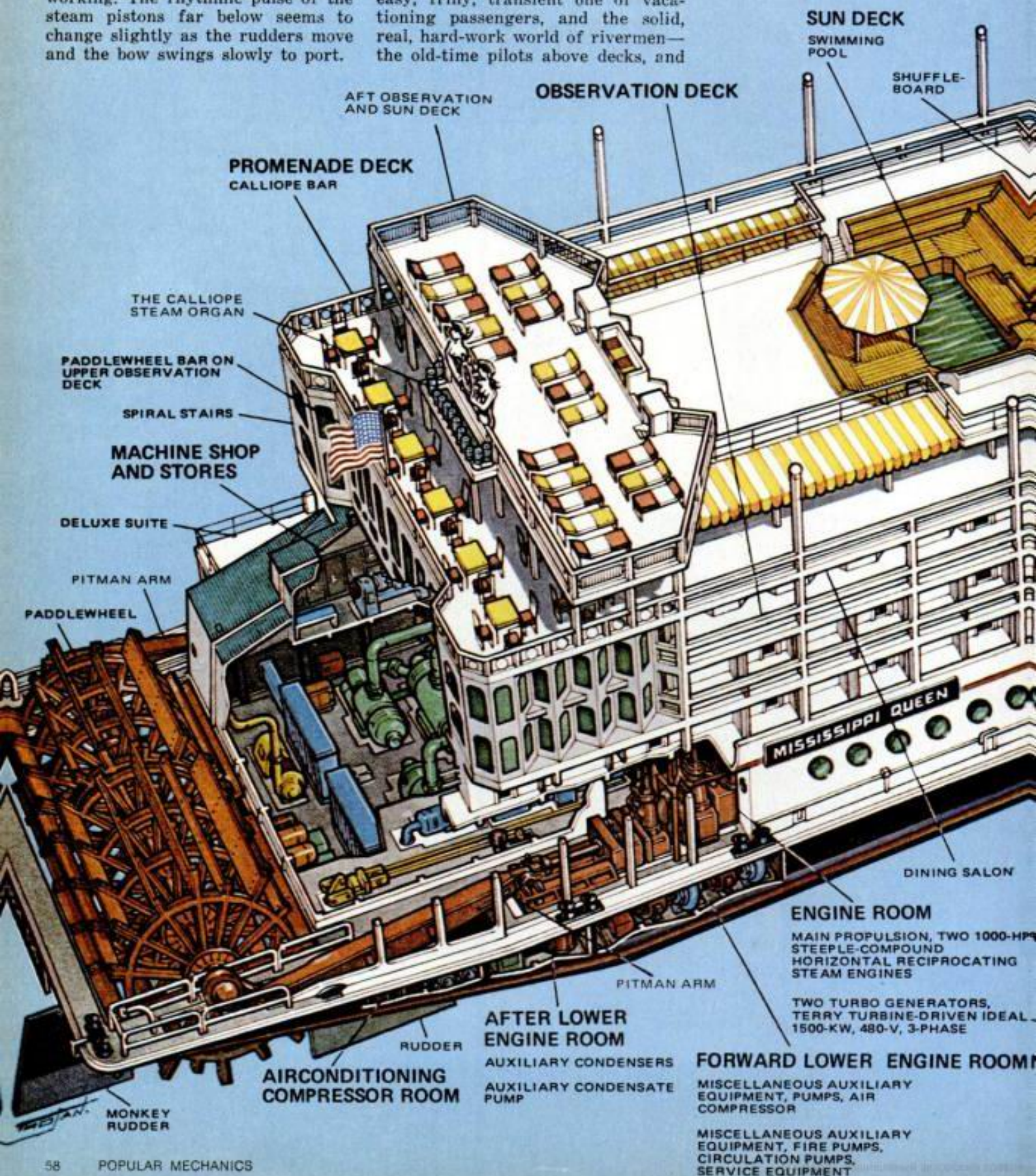
mammoth wheel worn by hands that are constantly turning it to steer. Instead, sticks are used as a helm. Steering sticks utilize air pressure to activate hydraulic pumps that move the *Queen's* five rudders. Sticks offer better control with less work than a wheel. As Capt. Gayle moves the sticks, I can hear the air system working. The rhythmic pulse of the steam pistons far below seems to change slightly as the rudders move and the bow swings slowly to port.

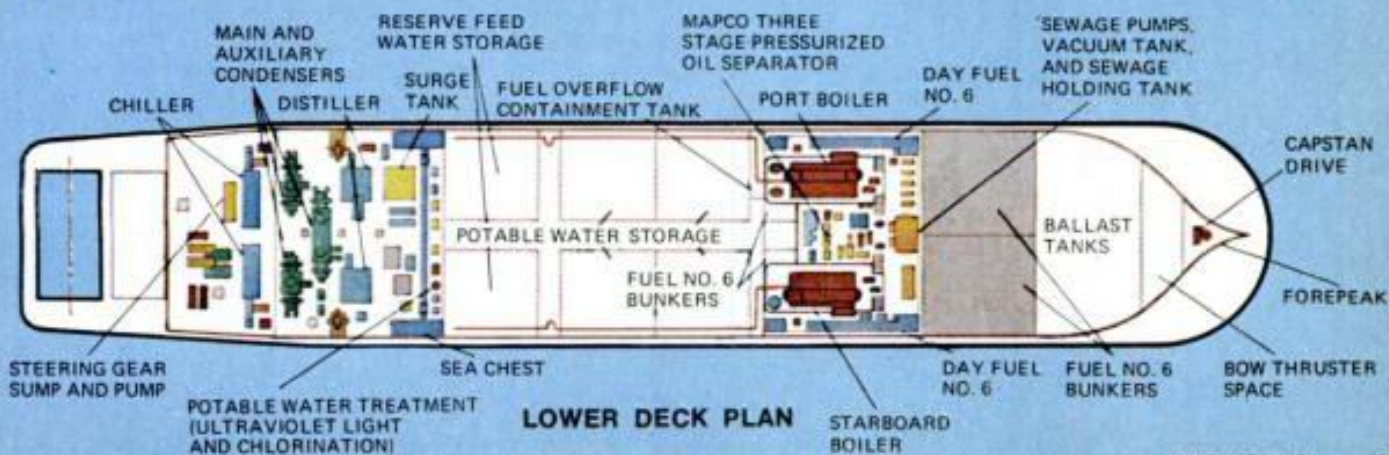
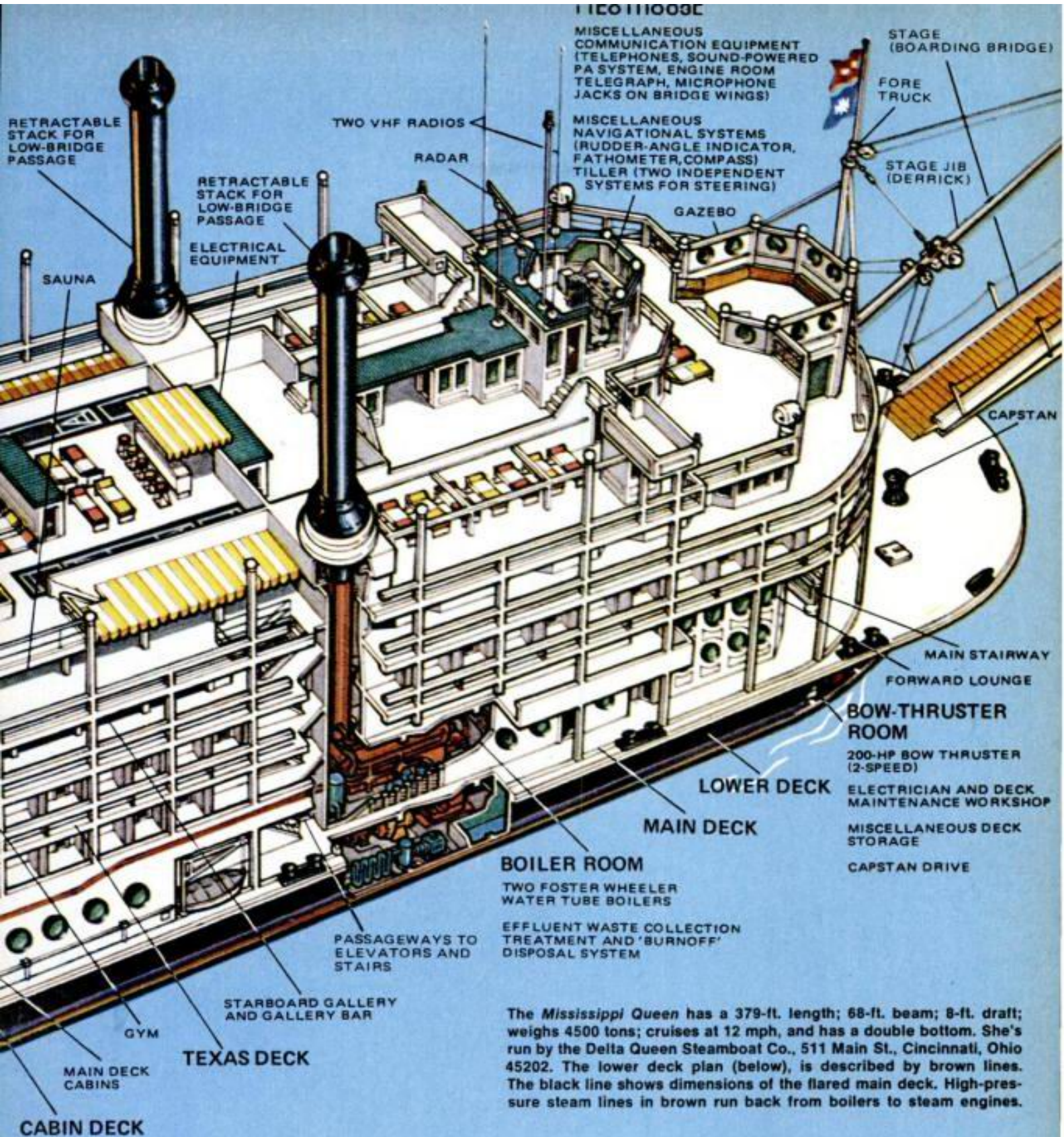
As I look back from the wheel-house across the sun deck, I see passengers lounging about the swimming pool, some reading, some sipping tall mint julips, others just watching the cotton fields and wooded banks slowly pass by.

I realize I am on the new with the old. I am living in two worlds: the easy, frilly, transient one of vacationing passengers, and the solid, real, hard-work world of rivermen—the old-time pilots above decks, and

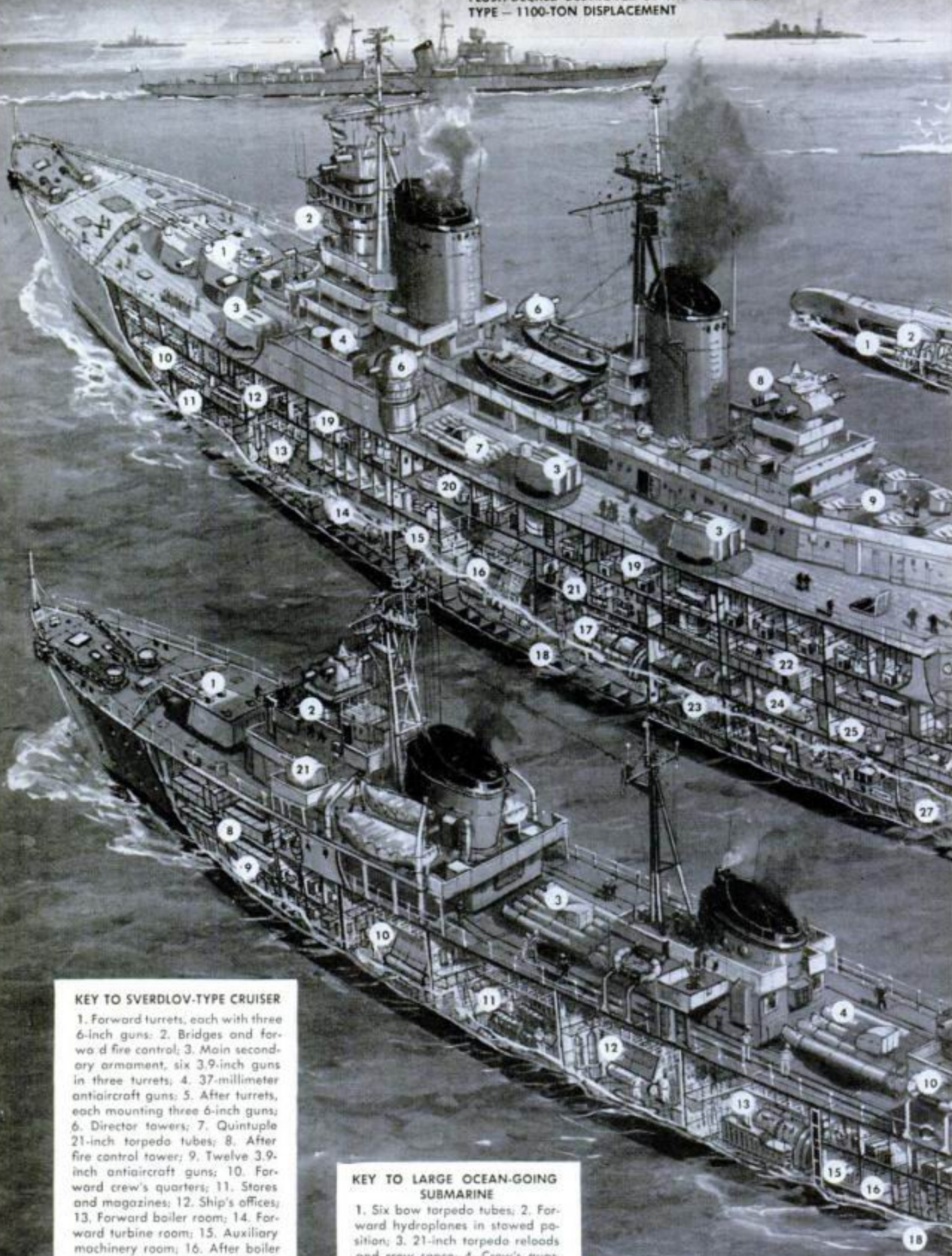
the precise engineers below decks.

The *Mississippi Queen* has elevators, a beauty shop, a 150-seat theater, and the luxury of the *Queen Elizabeth II* for her 400 passengers. She has a fine jazz band, fresh strawberries every morning, filet mignon and a grand salon. But for all her luxury, the *Mississippi Queen*





FLUSH-DECKED DESTROYER OF THE NEW ESCORT
TYPE — 1100-TON DISPLACEMENT



KEY TO SVERDLOV-TYPE CRUISER

1. Forward turrets, each with three 6-inch guns; 2. Bridges and forward fire control; 3. Main secondary armament, six 3.9-inch guns in three turrets; 4. 37-millimeter antiaircraft guns; 5. After turrets, each mounting three 6-inch guns; 6. Director towers; 7. Quintuple 21-inch torpedo tubes; 8. After fire control tower; 9. Twelve 3.9-inch antiaircraft guns; 10. Forward crew's quarters; 11. Stores and magazines; 12. Ship's offices; 13. Forward boiler room; 14. Forward turbine room; 15. Auxiliary machinery room; 16. After boiler room; 17. After turbine room; 18. Side fuel tanks; 19. Officers' cabins; 20. Wardroom; 21. Workshops; 22. Cadets' quarters; 23. Air-conditioning plant; 24. Hospital; 25. Recreation and propaganda room; 26. Crew's quarters; 27. Stores and magazines; 28. Fuel-oil tanks in double bottom

KEY TO LARGE OCEAN-GOING SUBMARINE

1. Six bow torpedo tubes; 2. Forward hydroplanes in stowed position; 3. 21-inch torpedo reloads and crew space; 4. Crew's quarters; 5. Wardroom; 6. Captain's cabin; 7. Twin 3-inch guns; 8. Streamlined conning tower; 9. Control room; 10. Wireless and radar room; 11. Engine compartment; 12. Switch room and electric motors; 13. After crew space; 14. After torpedo flat; 15. Snorkel stowed

NEW TYPE FLEET DESTROYER, FLUSH-DECK,
WITH 2100-TON DISPLACEMENT

SEAGOING PATROL SUBMARINE MAKES OVER 20 KNOTS
SURFACED AND 16 SUBMERGED. DISPLACES 1600 TONS

LARGE OCEAN-GOING SUBMARINE OF THE LATER "K" CLASS
DISPLACES 2900 TONS, HAS RANGE OF 20,000 MILES. MAKES
22 KNOTS ON SURFACE, 17 KNOTS SUBMERGED

LATEST TYPE OF HEAVY CRUISER, SVERDLOV CLASS, DISPLACES
17,000 TONS. IT IS 689 FEET LONG, HAS RANGE OF 8000 MILES
AT 20 KNOTS. DEVELOPS 130,000 HORSEPOWER AT 35 KNOTS

MODERN DESTROYER OF SKORYI CLASS (U.S.S.R. HAS AT LEAST 70
OF THESE) DISPLACES 3000 TONS FULLY LOADED, DEVELOPS 70,000
HORSEPOWER AT 38-40 KNOTS, IS 393½ FEET LONG

KEY TO SKORYI-CLASS DESTROYER

1. Forward turret, twin 5.1-inch guns; 2. Bridge and forward fire control; 3. Forward quintuple 21-inch torpedo tubes; 4. After quintuple 21-inch torpedo tubes; 5. After fire control; 6. After 3-inch gun turret; 7. After turret, twin 5.1-inch guns; 8. Crew's quarters; 9. Stores and magazines; 10. Forward boiler room; 11. Forward turbine; 12. After boiler room; 13. After turbine; 14. Officers' cabins; 15. Fans; 16. Cold-storage rooms; 17. Storerooms and magazines; 18. Fuel-oil tanks in double bottom; 19. Fresh-water tanks; 20. Mine doors; 21. Forward 3-inch gun turret

Traffic Tunnels Under Greenland's Icecap To Supply Our Arctic Outposts

By Elliott H. McCleary

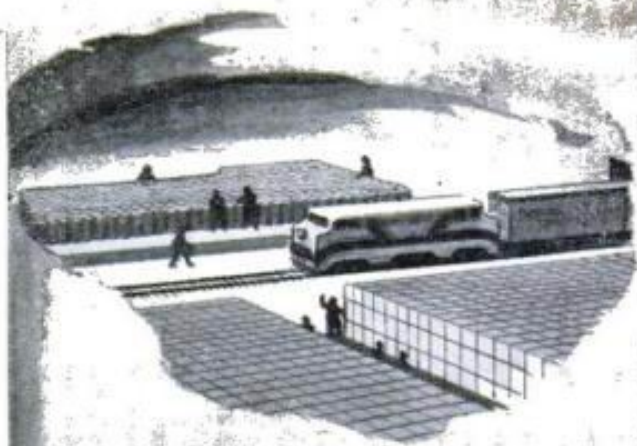
ARMY ENGINEERS are making transportation history with tunnels gouged through the crust of the Greenland icecap—tunnels that could in event of military necessity be snowy subways linking the outposts of our Arctic frontier.

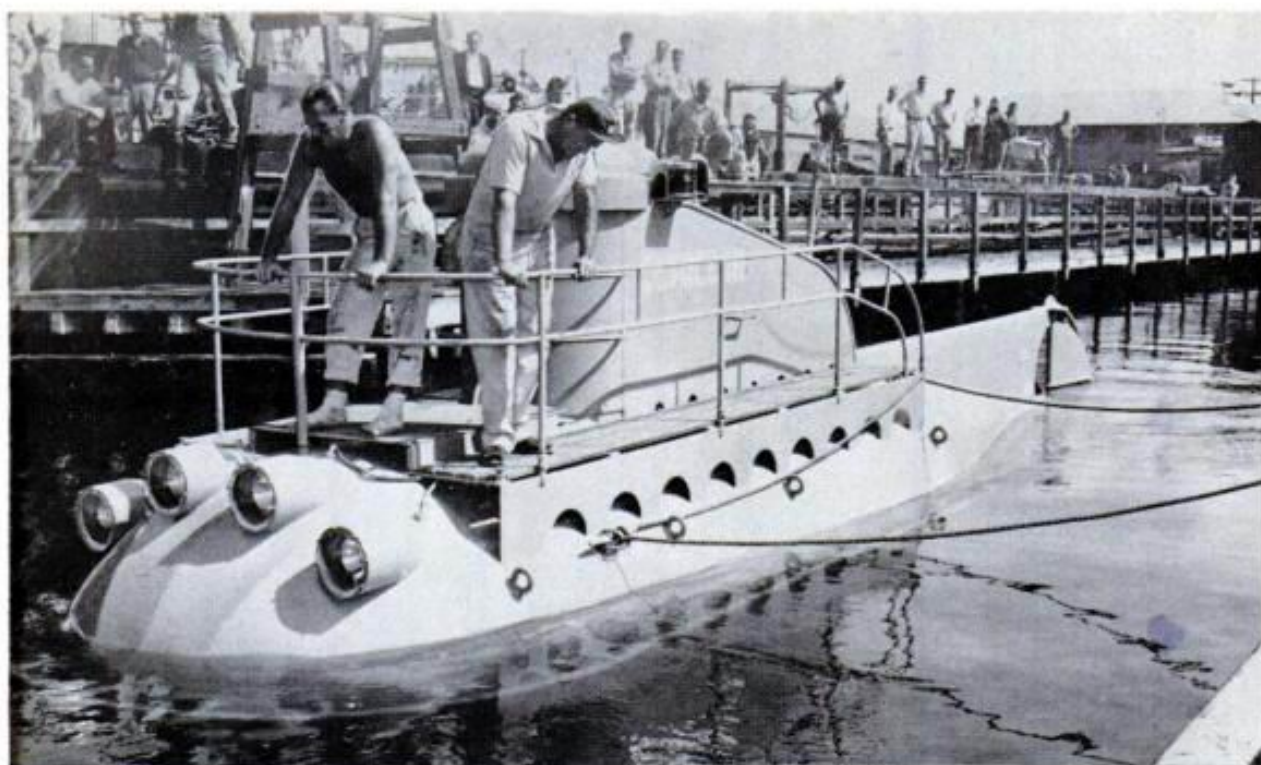
Their tool is a crawling snow eater with a massive bite. Its speed alone would never win a race, even in such forsaken country.

But as it slowly churns through the snowy frosting of the mile-thick ice sheet, its cylindrical digger whirling, its twin chutes spewing snow 20 feet into the air, it leaves a trench eight feet wide and three to five feet deep.

Three more passes with the snow eater, and the trench is 12 feet deep. Men place curved plywood forms on top of it and the forms are covered with snow.

Artist's conception shows the type of under-snow defenses which might be built far inland on top of icecap. Below, snow diggers gouge out a trench that is covered with removable forms and overlaid with layer of snow. Above and right, supply trains shunted from main railroad tunnel unload materials in under-snow storage rooms. Planes roll out of under-snow hangars to packed-snow landing field. Radar station, living quarters are also subsurface



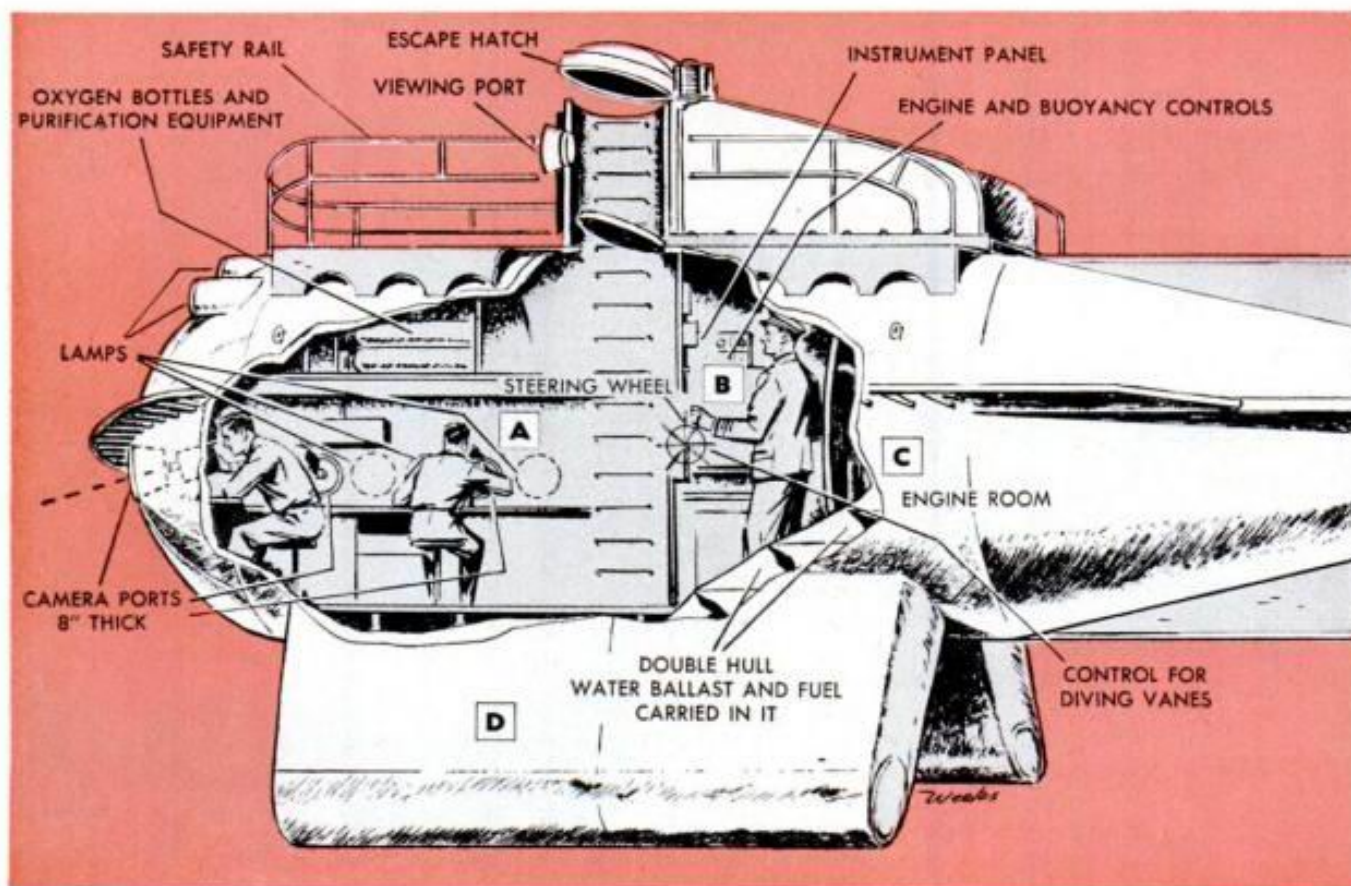


Little submarine carries a crew of five or six, has powerful lights for deep-sea motion-picture photography

Stubby Sub Cruises One Mile Deep

DEEP-SEA MONSTERS not yet seen by man will be sought in the *Cetacean*, a 50-ton submarine that can cruise a mile or more below the surface.

The craft has an underwater range of 35 miles and can lie for days on the ocean bottom, resting on two fat "legs" in which seven tons of storage batteries are carried.





Craft enters water for trim trials. Fat "legs" support it on ocean floor and carry storage batteries

In an emergency the double pressure hull could withstand the squeeze that would be encountered at a depth of five miles. Space between the two hulls is used to carry 2000 gallons of fuel for the 150-horsepower diesel engine which drives the craft on the



Inventor Martine checks propeller. Behind and above him are diving vanes and rudder that maneuver sub

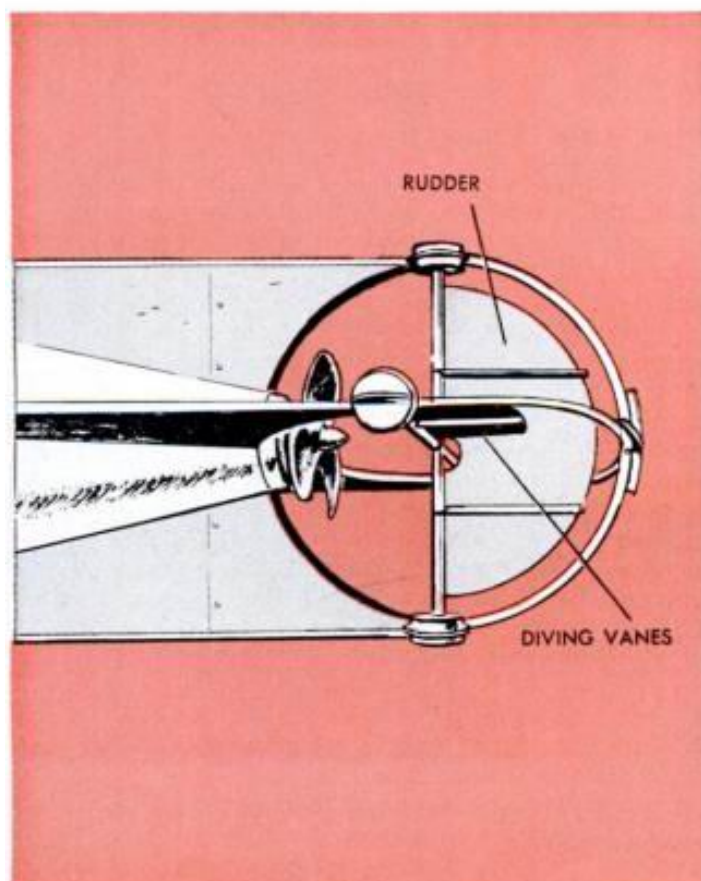
surface, as well as water ballast for controlling buoyancy during dives and ascents.

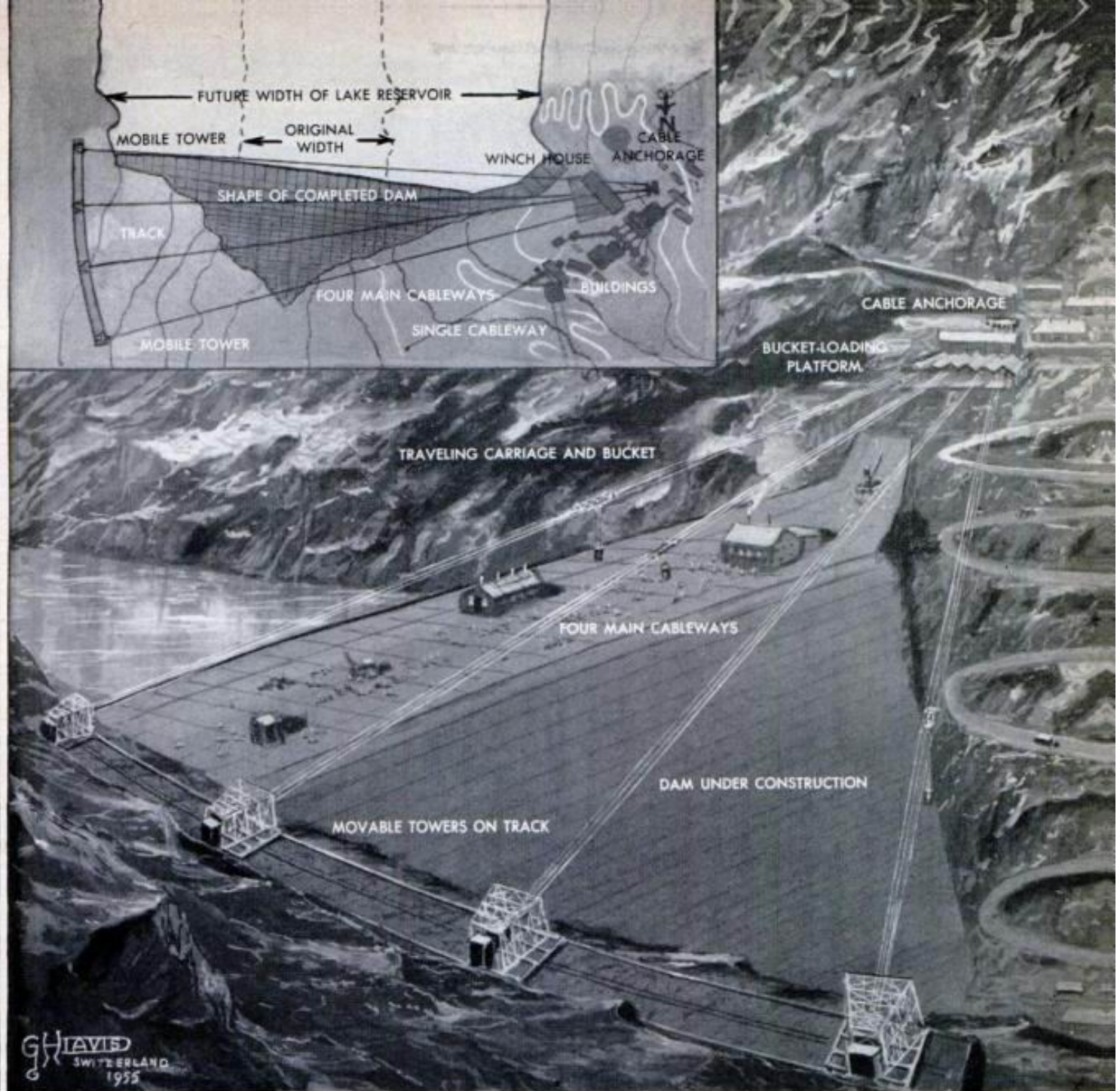
As a result of its relatively short length of 41 feet the *Cetacean* can be maneuvered with aircraft-type control surfaces—a rudder and elevators located aft of the propeller. It is designed to make nine knots on the surface, seven knots submerged.

The new submersible is fitted with powerful underwater floodlamps to provide illumination for exploring at great depths and for making wide-screen color motion pictures of interesting objects that are sighted. Edmund Martine, inventor, says that bait in the form of a slaughtered animal may be towed astern to attract deep-zone predators. Counting the photo staff, the crew consists of five or six men. The craft is fitted for other types of deep-sea research in addition to photography.

Martine, inventor and builder of large diving bells that are used on both coasts, made use of his long experience with submersibles in devising watertight fittings and other necessary gear to withstand the pressures that will be encountered at great depths. It is said that his craft is the world's first self-propelled submarine designed from the keel up for underwater research and exploration. Now undergoing diving trials on the West Coast, the *Cetacean* may soon be stationed in the Bahamas. ★ ★ ★

Cutaway shows interior of sub. Compartment A is for cameramen; B shows control compartment; C holds electric and diesel engines; batteries are in "legs" D





Materials and equipment for dam are carried by cableways anchored to mobile towers on a curving track

Concrete plant built on mountainside will furnish a total of 7,550,000 cubic yards of concrete to build dam





Thousands of tons of material must be brought up the side of the mountain from valley on this twisting road

the concrete plant and equipment sheds are the unique traveling anchorages of the four main cableways. Four great lattice-steel towers on multiple-wheel trucks support the ends of the cables. The towers rest on a curving track that enables them to move from side to side. With this arrangement, the cables can be moved to cover any point of the dam, and materials and gear can be lowered to desired points in the working area.

The huge power house at Fionnay is being cut out of the solid rock of the mountain so that its front will project slightly over the sheer face of the mountainside.

Its spacious generator room houses six

generators. Controls and transformers are housed in other rooms, and an administration headquarters, auxiliary service installations, living quarters and workshops are housed in adjacent buildings.

The water falls through the outfall tunnels from the dam in three stages. Having passed through the gates in the dam, it passes controlling valves and pressure regulators and surge valves before reaching the power station. There it drives the water turbines which generate the power. When finished, the gigantic dam will provide power to increase greatly the productive energy of small but extremely industrialized Switzerland. ★ ★ ★

Anticollision Light for Aircraft

Called a "relative-danger light," a new running light for airliners indicates the plane's course to approaching planes. It was developed by an airline pilot. The light actually consists of three lights in one unit. The front light flashes forward three times a second. The middle light flashes to the sides once a second and the

back light flashes astern once every three seconds. The pilot of an approaching plane can determine the position and course by the duration of the flash he sees. Instead of the conventional red light, the new navigational aid uses a blue-white xenon light, known to photographers as a stroboscopic light, which has great fog penetration.

also located on the banks of the distant River Rhone.

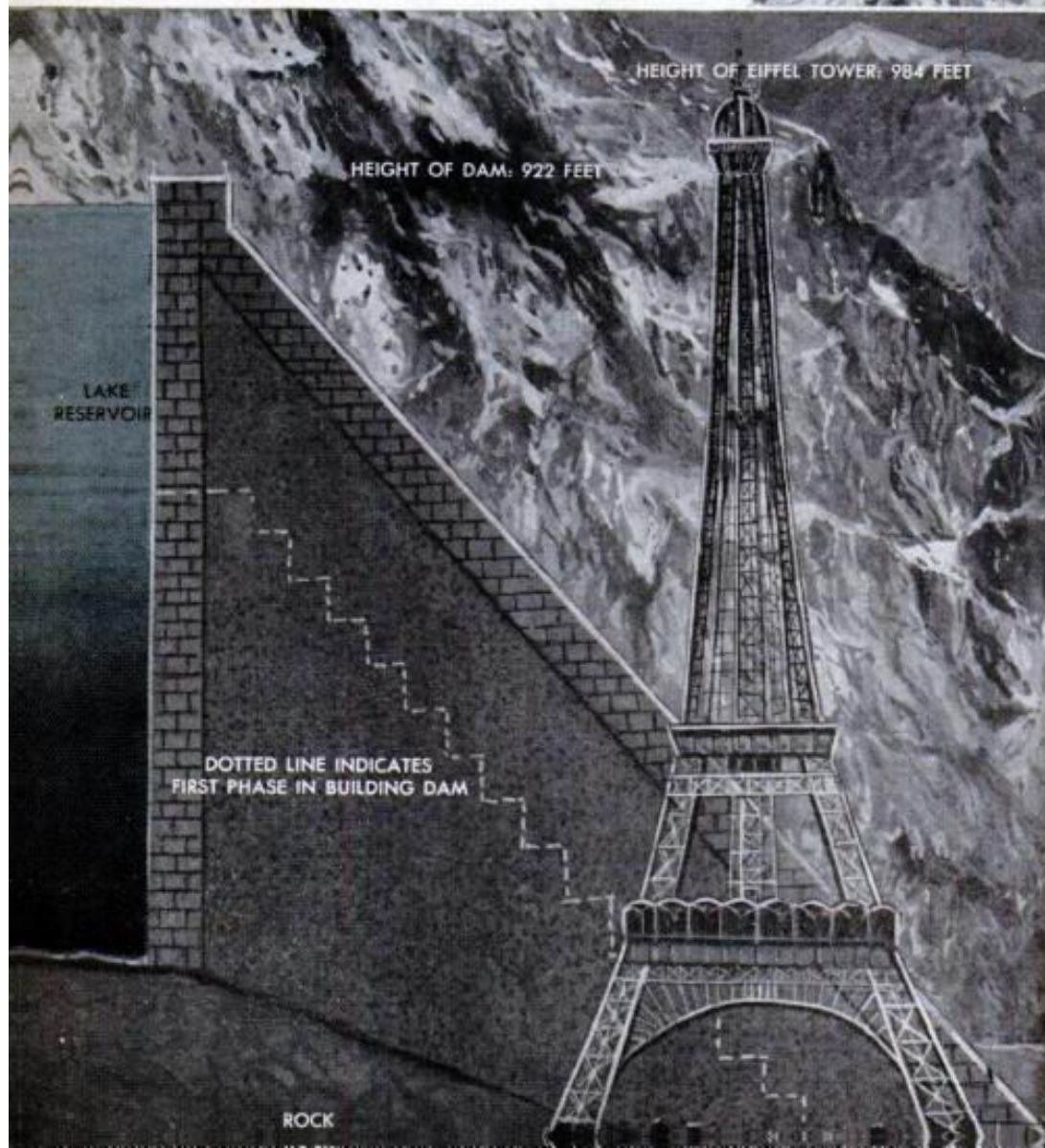
Approximately 20 large and small glaciers will be tapped to supply the dam with water. During spring, summer and autumn, water from the melted surface of the glaciers will spill into the tunnels and rush in torrents through them to the reservoir.

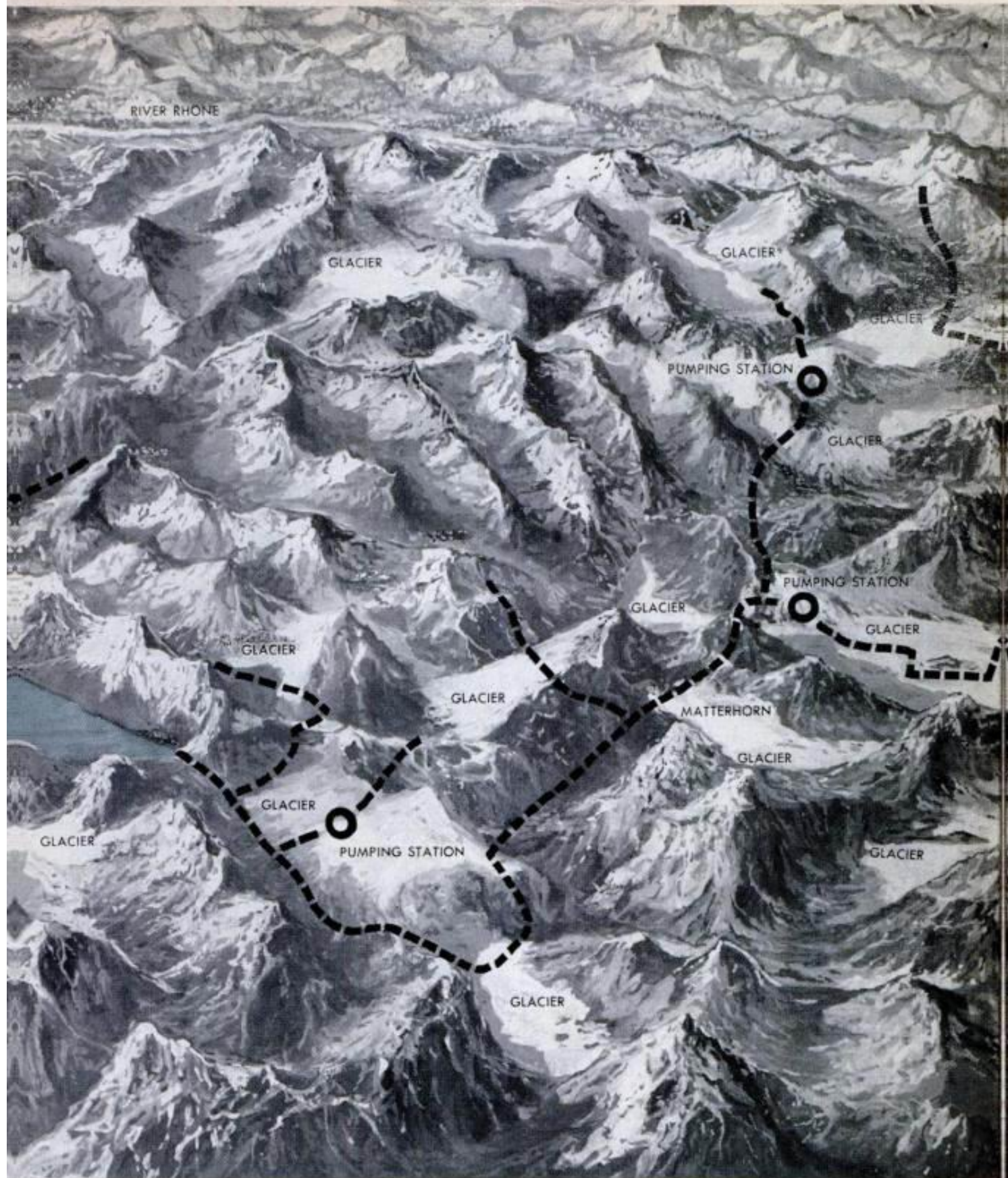
Total length of the water tunnels will be 103 miles. The force of gravity will carry the water most of the way, but at certain points electric pumps will boost it over humps in the subterranean tunnels. The tunnels vary in size, but average 12 feet in diameter.

Last summer, approximately 2000 men working in two shifts (a day shift of 11 hours and a night shift of 10 hours) toiled on the dam. In the winter, six to eight feet of snow covers the area, but work goes on in the tunnels.

Gigantic tools, including much American equipment, have been brought up to the dam site on twisting supply roads cut into the side of the mountain. A small town has

Dam will be almost as tall as the Eiffel Tower. It will be 72 feet thick at top, 721 feet thick at base





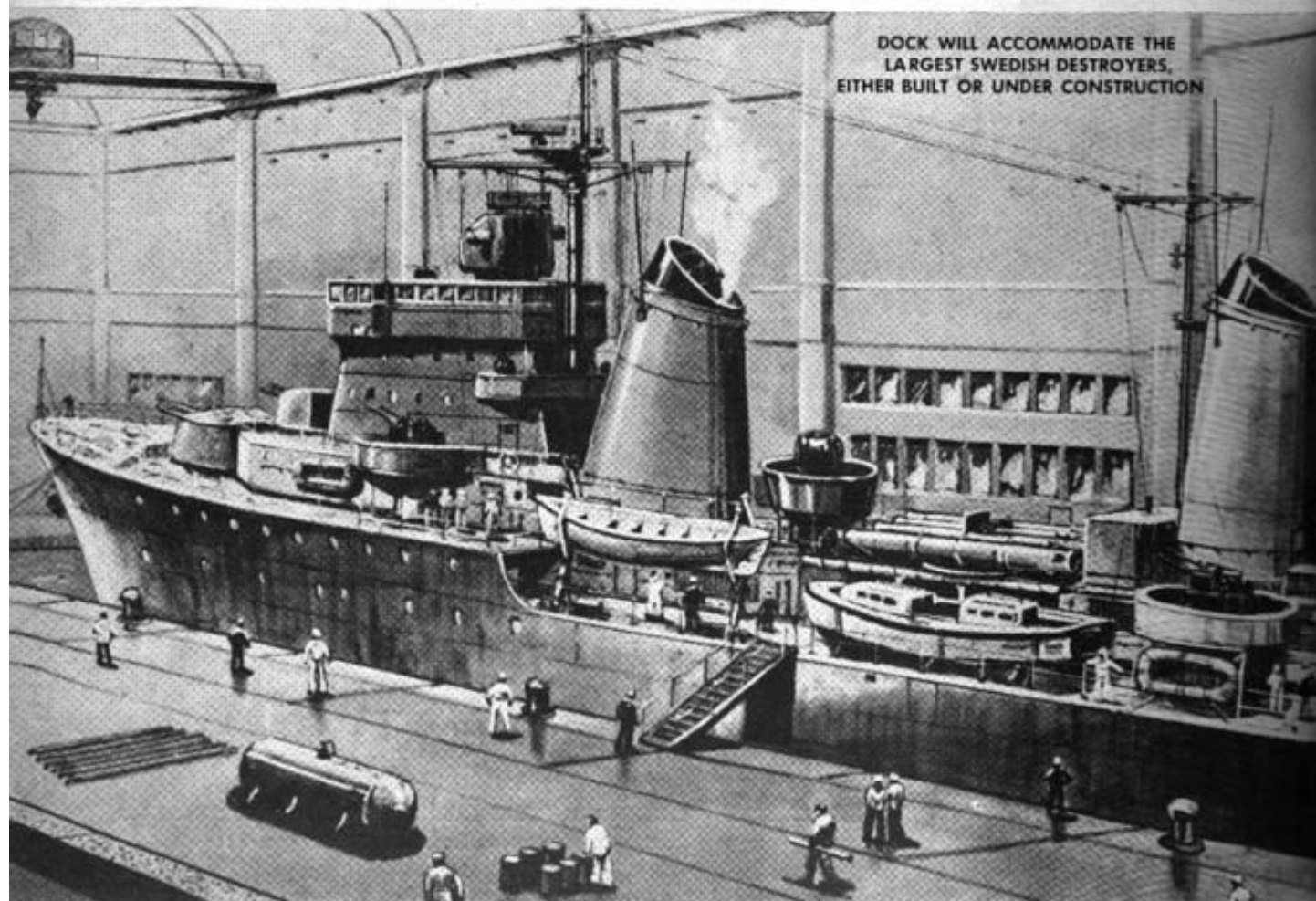
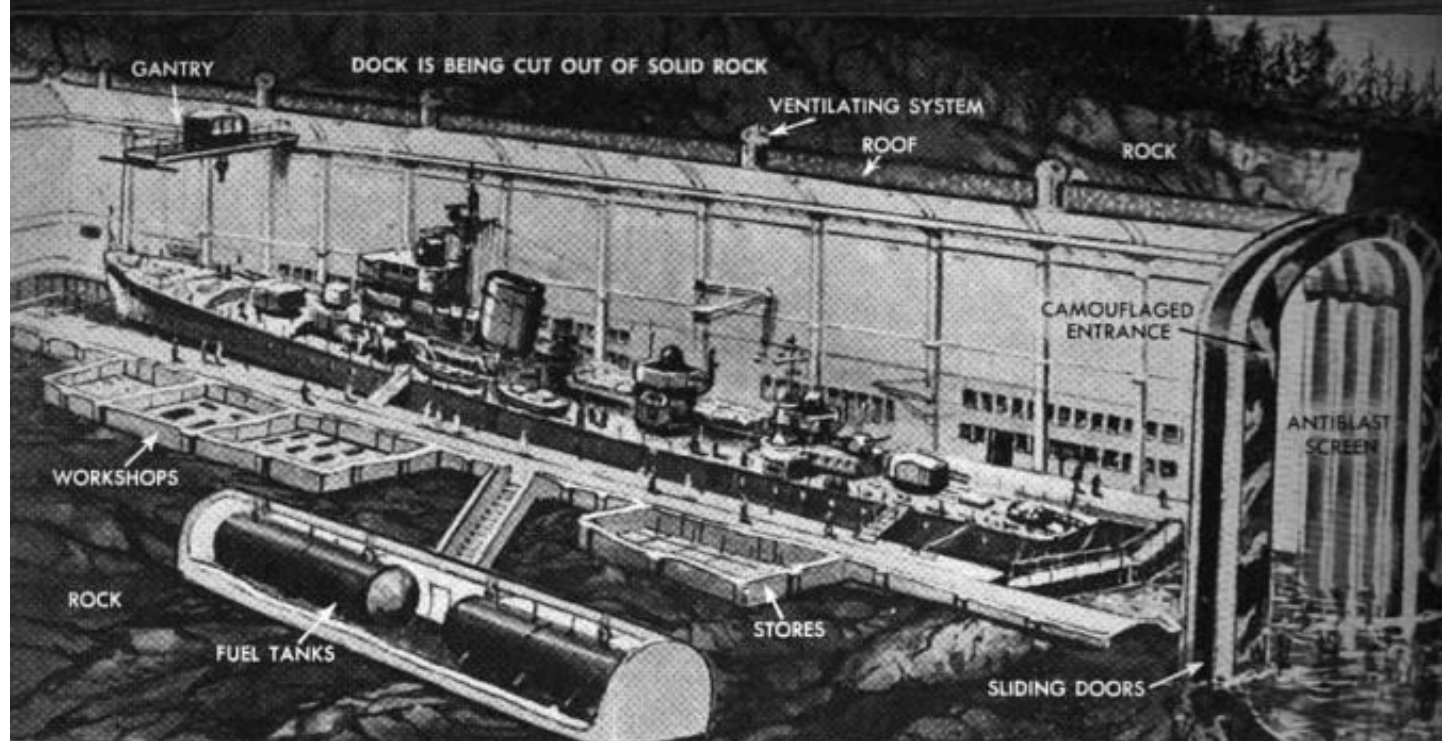
With assists from pumping stations, water from melting glaciers will flow through tunnels to dam reservoir

been built on the side of the mountain to house the construction workers.

Concrete for the dam is produced by a special plant constructed for the purpose. All the screen washing and secondary crushing of gravel is performed in the plant. Sheds protect the machinery and the conveyor belts that carry the material on its way. The finished concrete is loaded onto cable cars that swing out over the dam and

dump their loads into the forms below. Huge equipment, including giant bulldozers, can be carried by the cableways and lowered into position on the working area below. Each of the cableways, stretching the width of the chasm, spans a distance of 2900 feet. The carriages that move on the cables have a traveling speed of 17 feet per second.

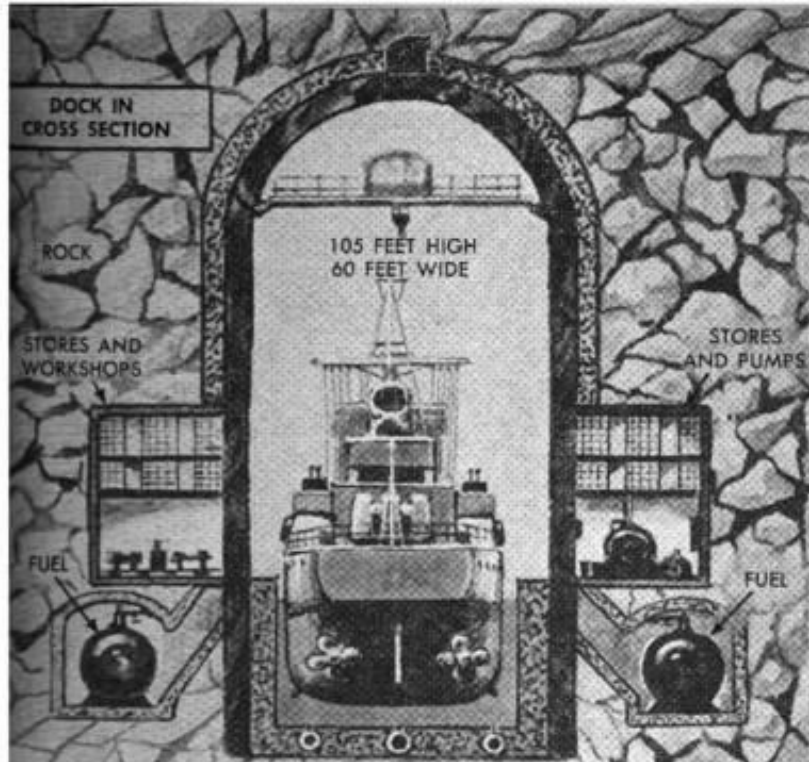
On the opposite side of the valley from



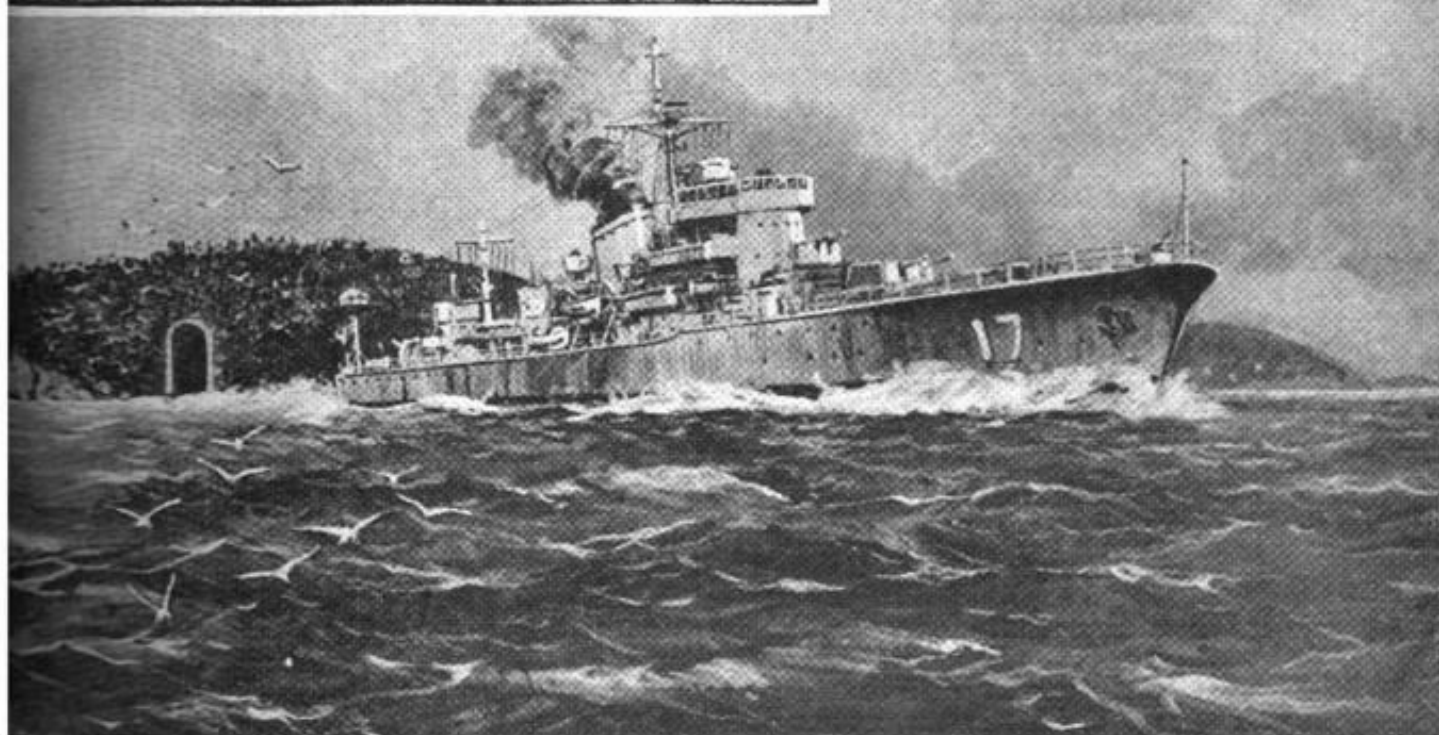
oblique angles into the rock to protect the tunnels against the impact of air and water pressure in case of enemy attack. So far, the largest tunnel is 96 feet high and 57 feet wide. Not only docks, but also repair depots, workshops, storage areas and living quarters for personnel have already been built deep in the granite. Gradually Sweden plans to house more and more of her combat strength in similar tunnels.

The air force also is well protected with

underground hangars for an estimated 1500 planes. There are permanent installations for the coast artillery. A control center for high military and civil authorities has been buried far below the earth's surface, as well as radar controls, workshops, supply depots, fortifications and military rock shelters. About 500 underground shelters are either completed or well underway. Millions of cubic feet of granite have been steadily blasted away since the end of



SWEDISH DESTROYER LEAVES THE UNDERGROUND DOCK. DARKENED DOCK AND CAMOUFLAGED ENTRANCE WILL MAKE THE DOOR ALMOST INVISIBLE AGAINST THE PINE-COVERED ISLAND

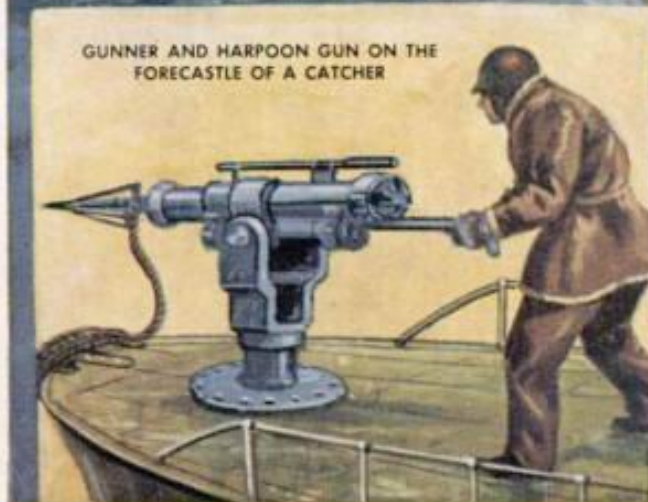


World War II, making a close network of hidden chambers along the entire Swedish coast and at certain strategic inland centers. Near the Arctic Circle one of the world's largest power plants has been buried far beneath the surface. With its generator as large as a cathedral, 380,000-volt Haespranget lies, as do power plants in Canada and the western part of the United States, so deep within the bowels of the earth that even a direct hit would not de-

stroy it. In this age of rapid oil consumption it is exceedingly difficult to store enough fuel to keep a nation going, but Sweden has gone a long way in this direction. Enormous underground cement tanks, lined with metal, have been built in scattered locations. In some areas it has been possible to take over abandoned mines, converting them into almost bottomless storage tanks where increasing supplies of fuel are being hidden away.



GUNNER AND HARPOON GUN ON THE FORECASTLE OF A CATCHER



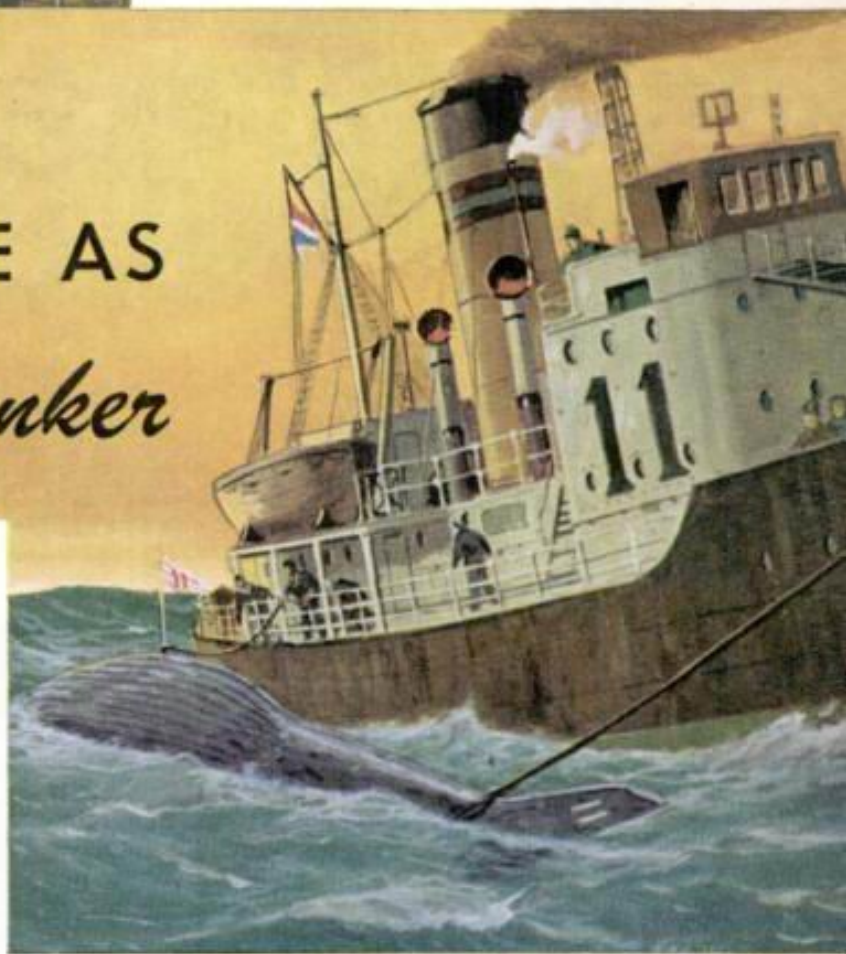
A Dutch "corvette" catcher approaches its target, a spouting blue whale. Gun on forecastle fires a harpoon that explodes and snaps open in whale

Whaler TO DOUBLE AS Supertanker

ICEBERGS and Antarctic gales hold little terror for the whaling fleets that yearly hunt their prey at the bottom of the world. Modern, radar-equipped "floating factories," each accompanied by a brood of smaller vessels, harvest the seas with systematic and determined thoroughness.

Most modern and biggest of the floating factories will soon be the Dutch vessel, *Willem Barendsz II*, scheduled for action in 1956. Carrying a crew of 500 officers and men, the 635-foot vessel will have

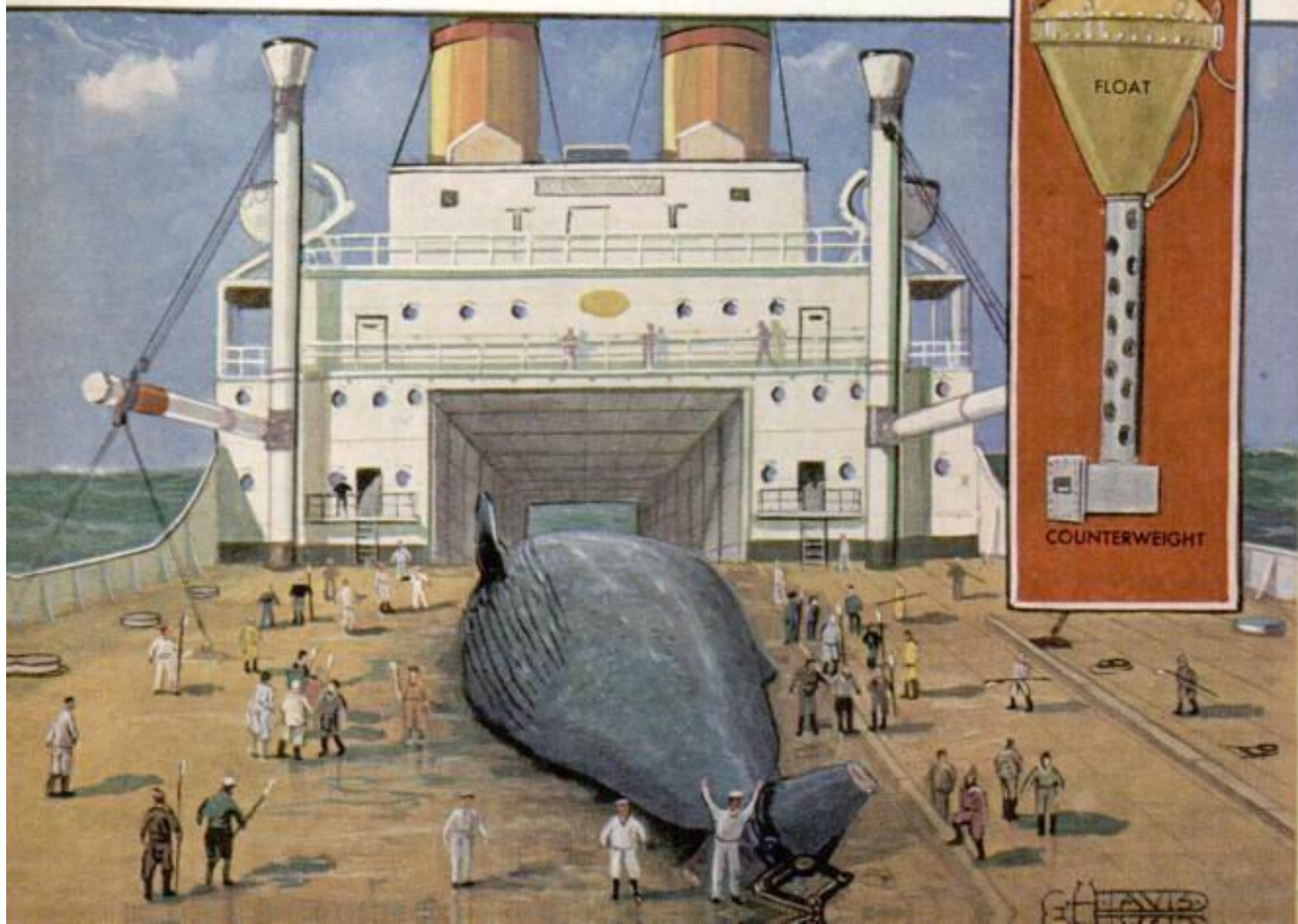
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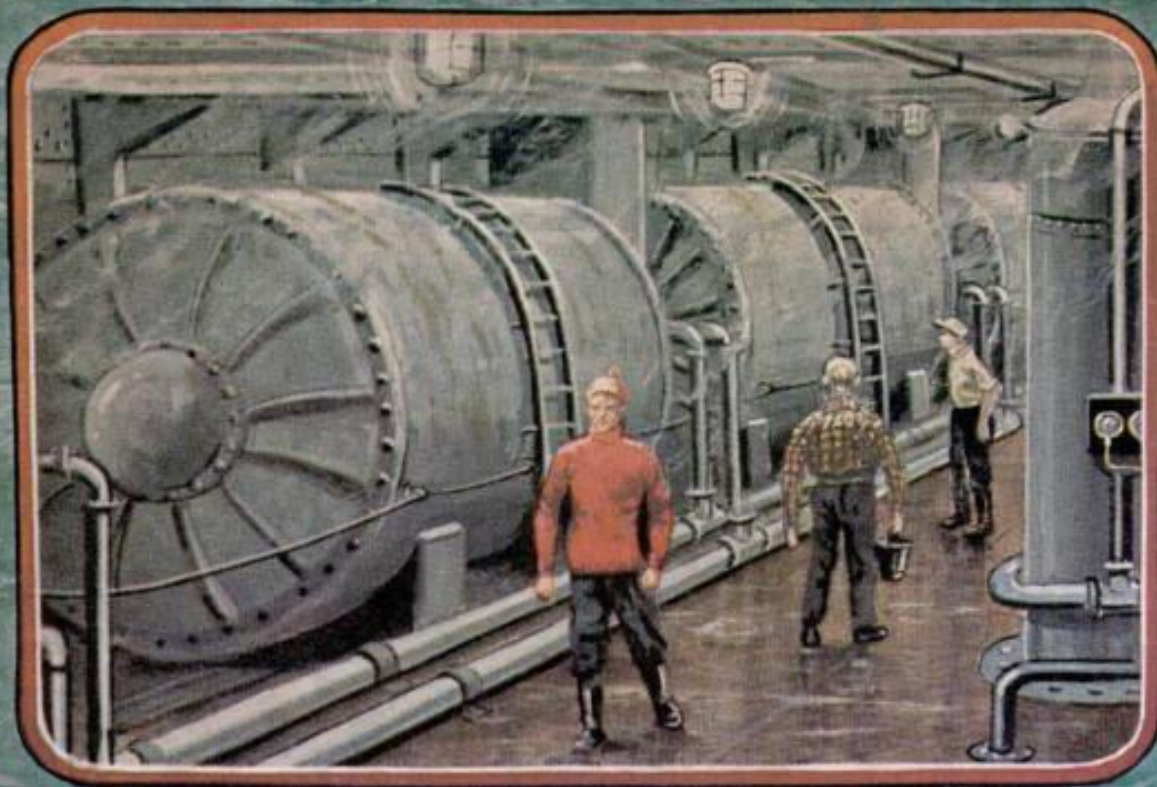


Dutch trawler-type catcher prepares to cast loose whale it has killed. Inflated to keep it afloat, marked with a flag and a number cut into flukes, whale will be retrieved by another boat



Radio beacon in buoy transmits a distinctive signal that helps a retrieving vessel locate a floating whale carcass. Dead whales may drift for miles after killer vessels cast them loose. In background is one of the latest Norwegian catcher ships. Below, a blue whale just after it has been pulled from sea up slanting skidway to ship's deck





A CORNER OF THE FACTORY DECK

"WILLEM BARENDZ II"

Dead weight — 26,400 tons
 Over-all length — 635 feet
 Beam — 86 feet
 Depth — 58 feet
 Crew — 500 officers and men
 Speed — 14 knots

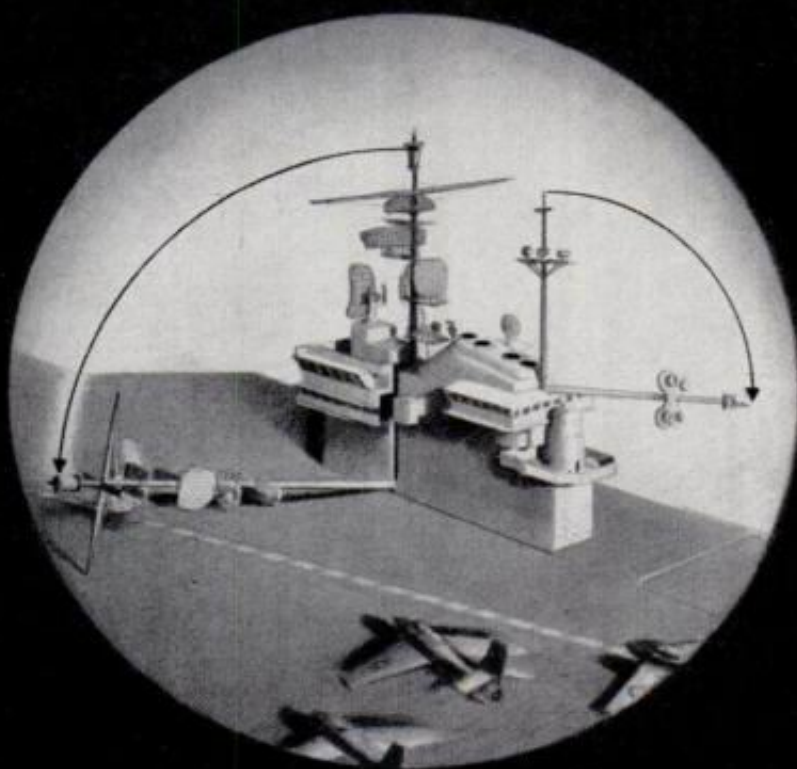
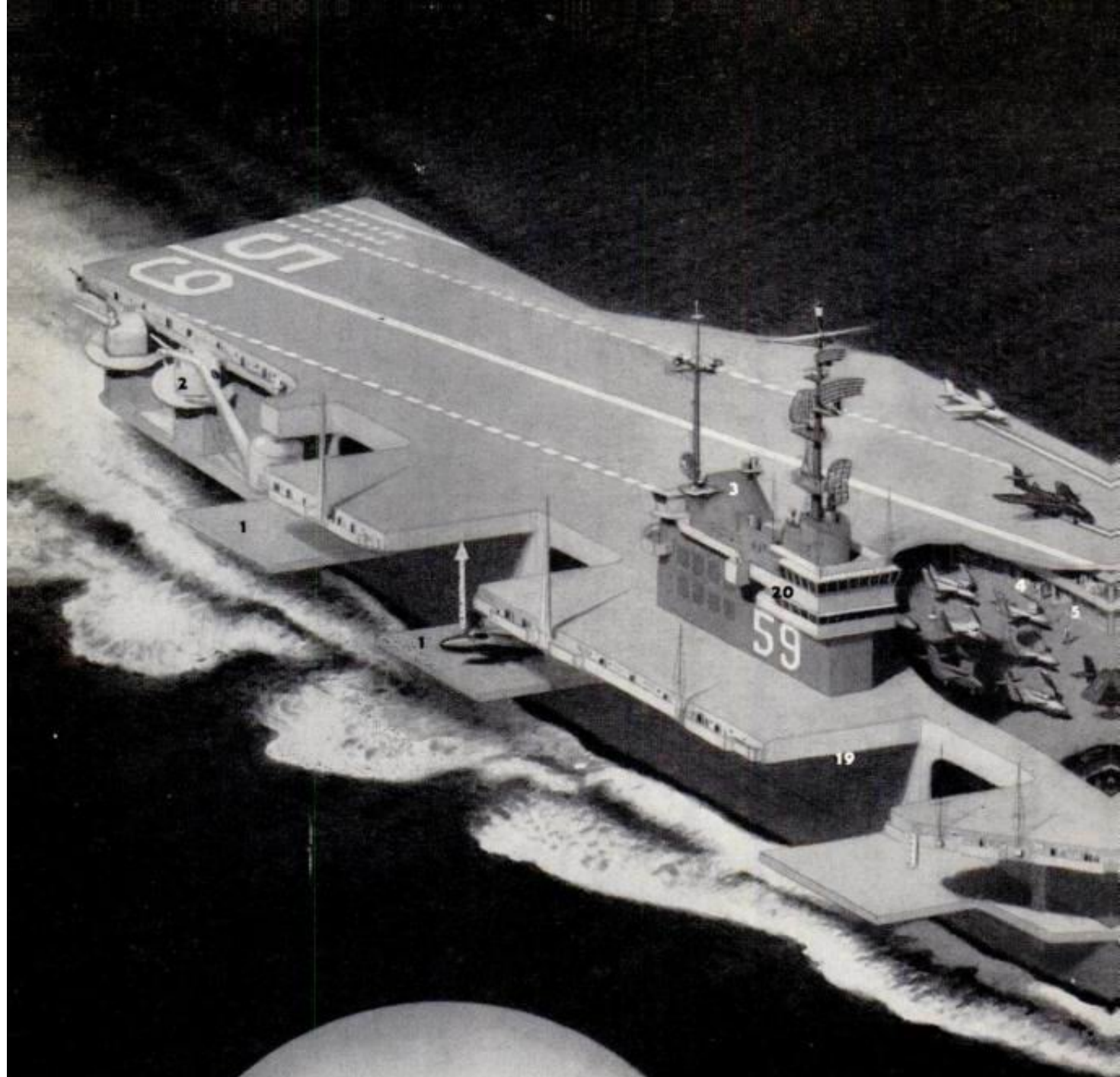




- | | |
|--|---------------------------------------|
| 1. Whale skidway | 15. Meat-and-bone boilers |
| 2. Whale-towing bollards | 16. Final-separation plant |
| 3. Capstans | 17. Whale-oil tanks |
| 4. Spare propellers | 18. Whale-hauling winches |
| 5. Sleeping quarters | 19. Derrick post |
| 6. Factory steam boilers | 20. Mixture tank |
| 7. Diesel propulsion engines | 21. "Coast guard" tank |
| 8. Fuel bunkers | 22. Drier of meat-treatment plant |
| 9. Blue whale on flensing deck | 23. Bone-meal plant |
| 10. Factory control room | 24. Radar scanners, direction finders |
| 11. Separator tanks | 25. Crow's nest |
| 12. Settling tanks | 26. Radio cabins and wheelhouse |
| 13. Chute hole | 27. Bridge |
| 14. Blubber boilers | 28. Anchor winch |
| 30. Officers' quarters, administrative offices, galley | 29. Bow lookout |

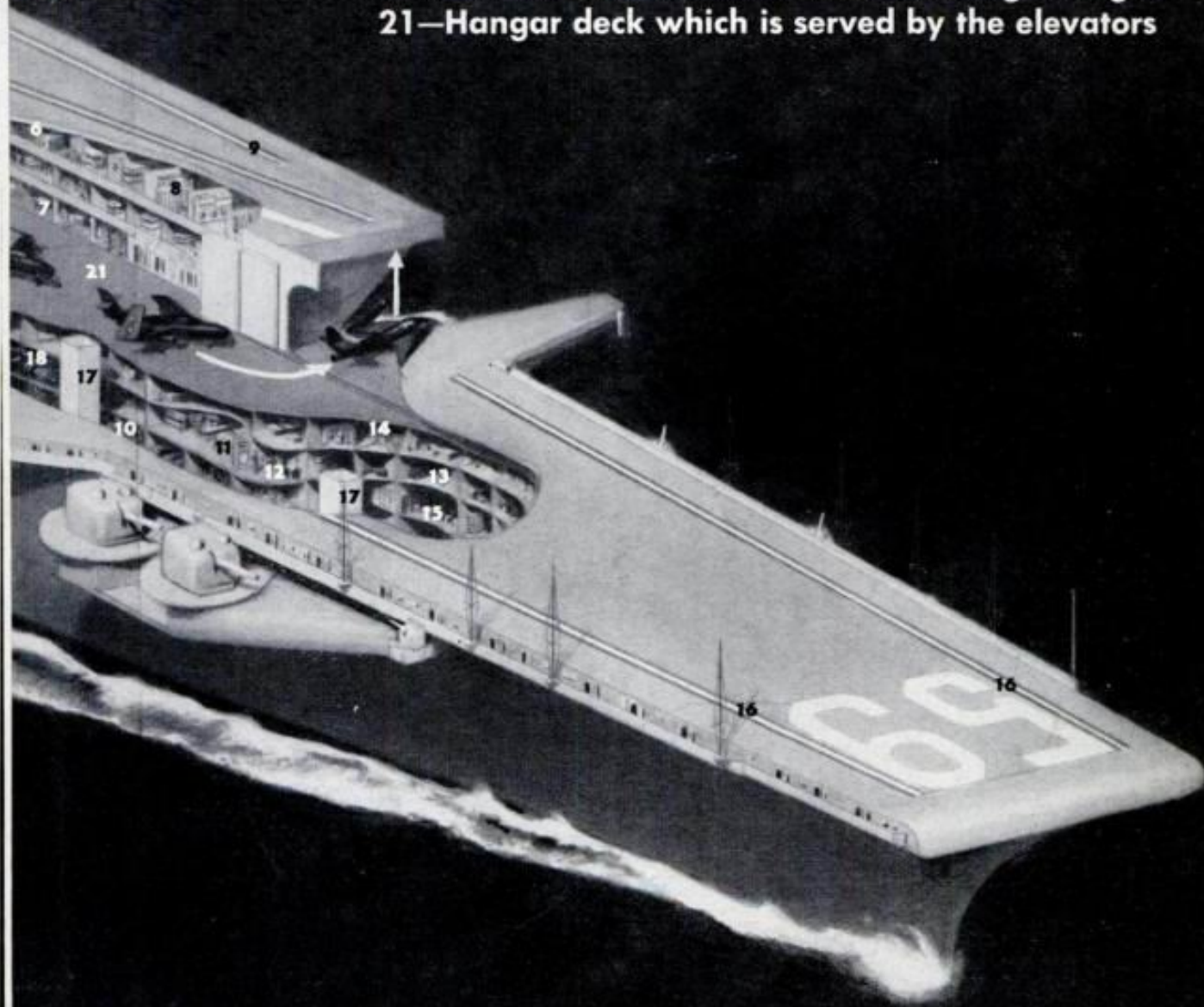
THE "WILLEM BARENDZ II" AS SHE WILL APPEAR WHEN COMPLETED



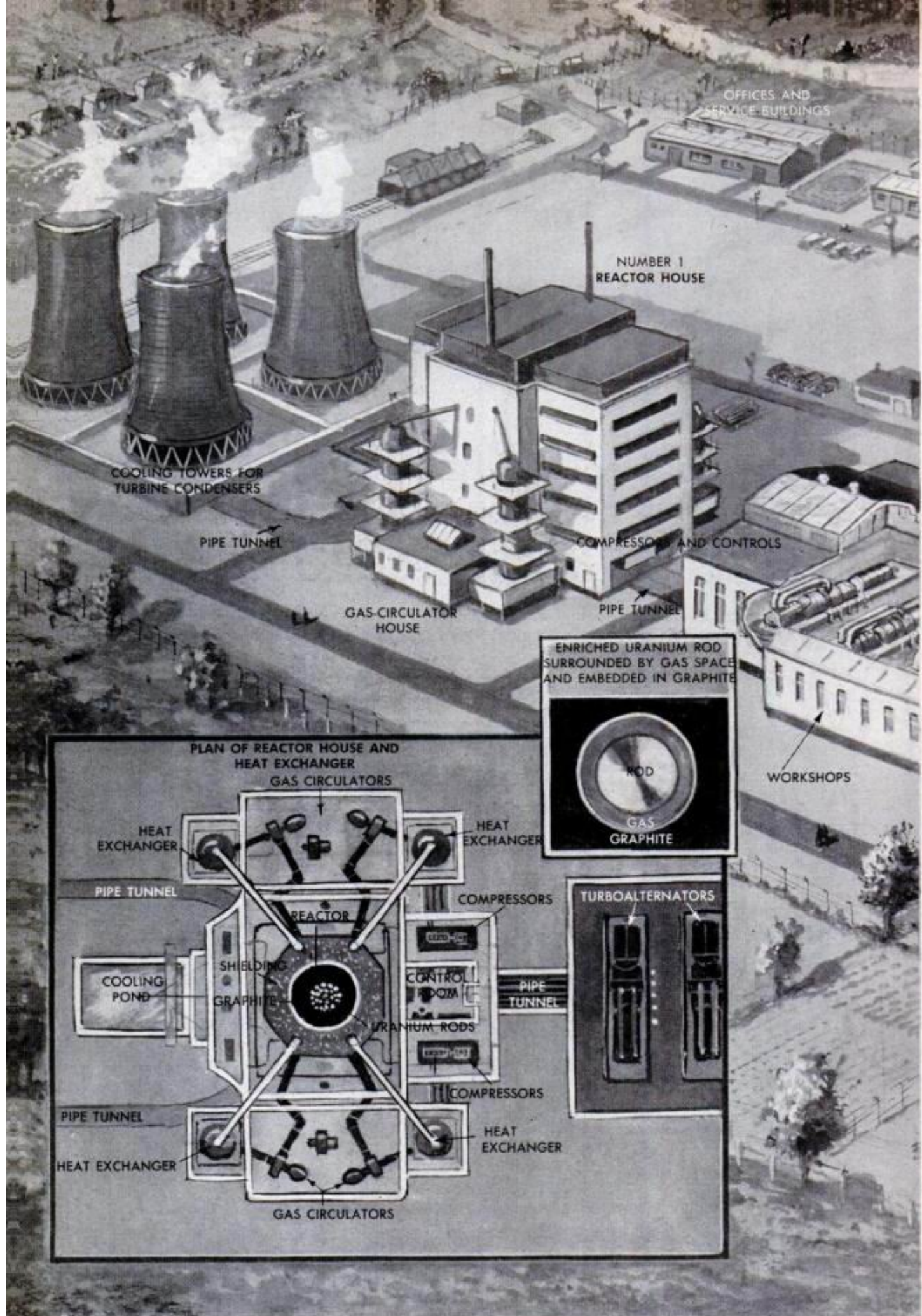


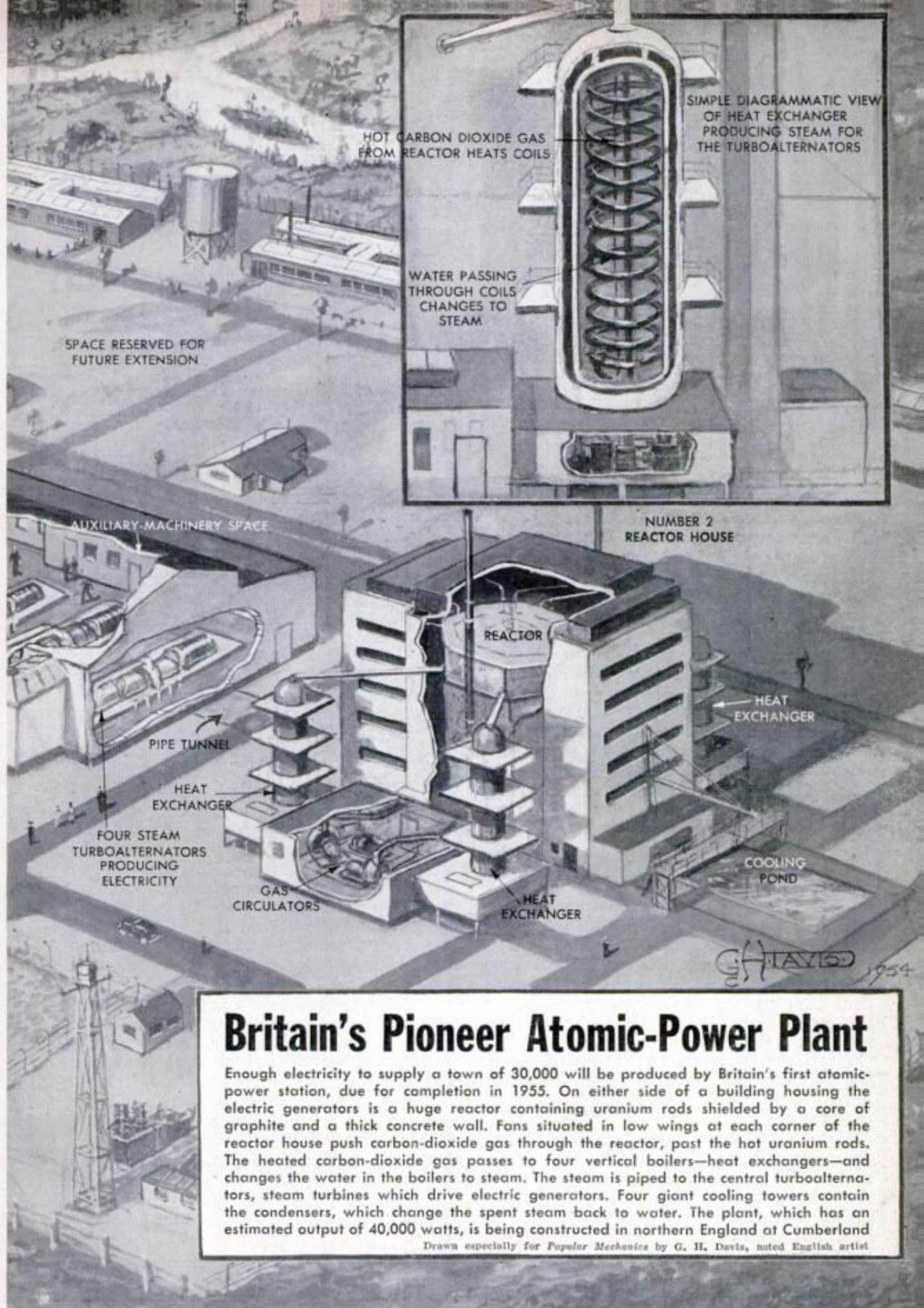
**MASTS TIP LIKE DERRICK BOOMS TO PERMIT
SHIP TO CLEAR THE BROOKLYN BRIDGE**

1—Starboard elevators lift 75,000 pounds each. 2—Five-inch gun battery mounted on each quarter. 3—Sloped stack. 4—Machine shops. 5—Escalator from ready room. 6—Flight offices. 7—Officers quarters. 8—File rooms. 9—Port catapults. 10—Storage space. 11—Hospital. 12—Operating room and laboratory. 13—Corpsmens quarters. 14—Dispensary. 15—Machinery and storage. 16—Forward catapults. 17—Elevator shafts. 18—Machinery spaces. 19—Flight deck overhangs 60 feet on each side. 20—Island conning bridge. 21—Hangar deck which is served by the elevators



A. Leyden Frost





Britain's Pioneer Atomic-Power Plant

Enough electricity to supply a town of 30,000 will be produced by Britain's first atomic-power station, due for completion in 1955. On either side of a building housing the electric generators is a huge reactor containing uranium rods shielded by a core of graphite and a thick concrete wall. Fans situated in low wings at each corner of the reactor house push carbon-dioxide gas through the reactor, past the hot uranium rods. The heated carbon-dioxide gas passes to four vertical boilers—heat exchangers—and changes the water in the boilers to steam. The steam is piped to the central turboalternators, steam turbines which drive electric generators. Four giant cooling towers contain the condensers, which change the spent steam back to water. The plant, which has an estimated output of 40,000 watts, is being constructed in northern England at Cumberland

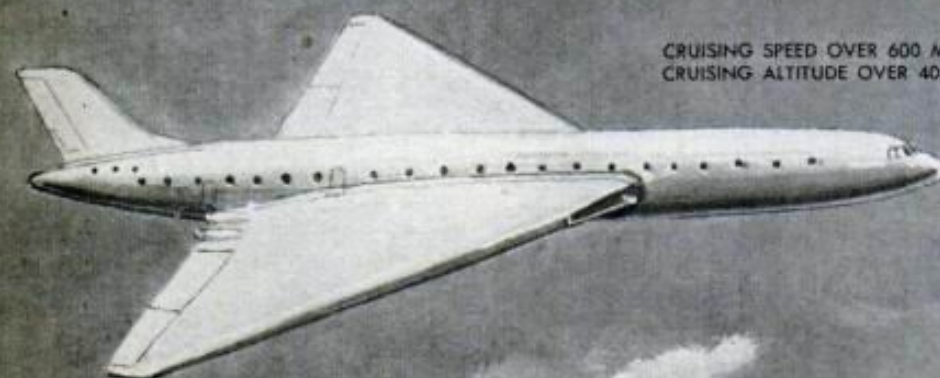
Drawn especially for *Popular Mechanics* by G. H. Davis, noted English artist



COCKTAIL LOUNGE

AVRO ATLANTIC

CRUISING SPEED OVER 600 MILES PER HOUR
CRUISING ALTITUDE OVER 40,000 FEET



MIDSHIP CABIN
(15 PASSENGERS)

PANTRY

FORWARD CABIN
(24 PASSENGERS)

TOILET

COMMUNICATIONS AND
ENGINEERING OFFICERS

CAPTAIN AND
SECOND PILOT

MAIN DOOR

FORWARD BAGGAGE AND
FREIGHT COMPARTMENT

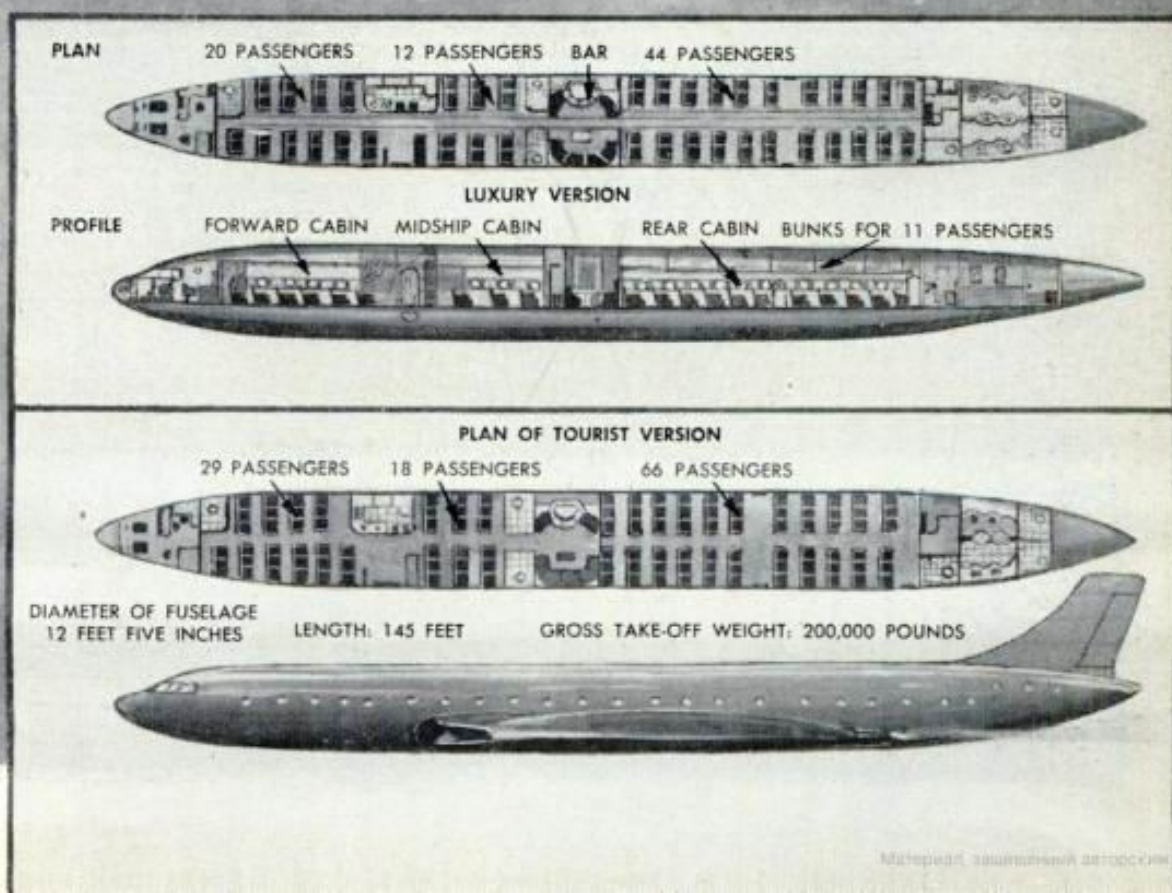
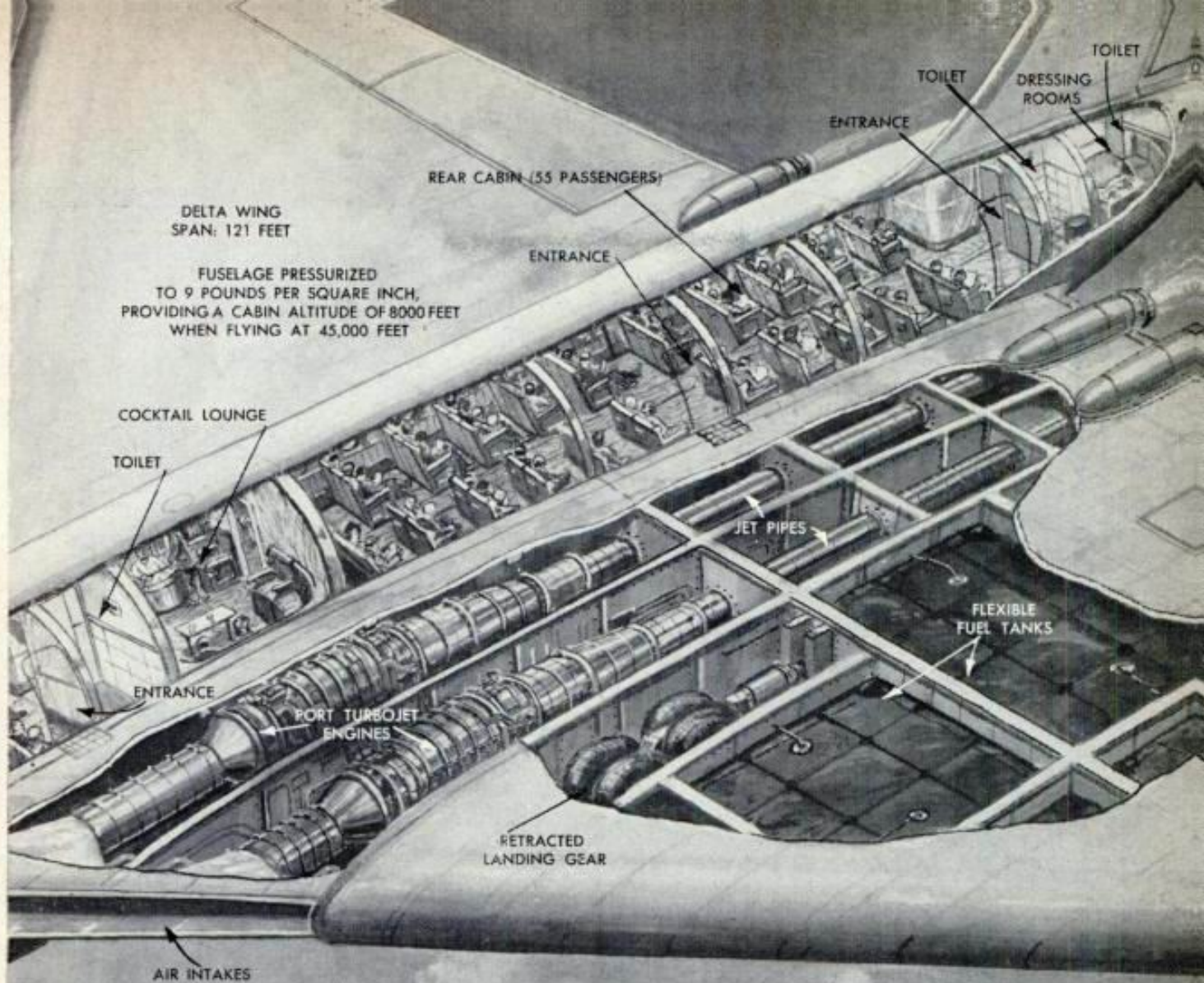
ALL CABINS
AIR-CONDITIONED

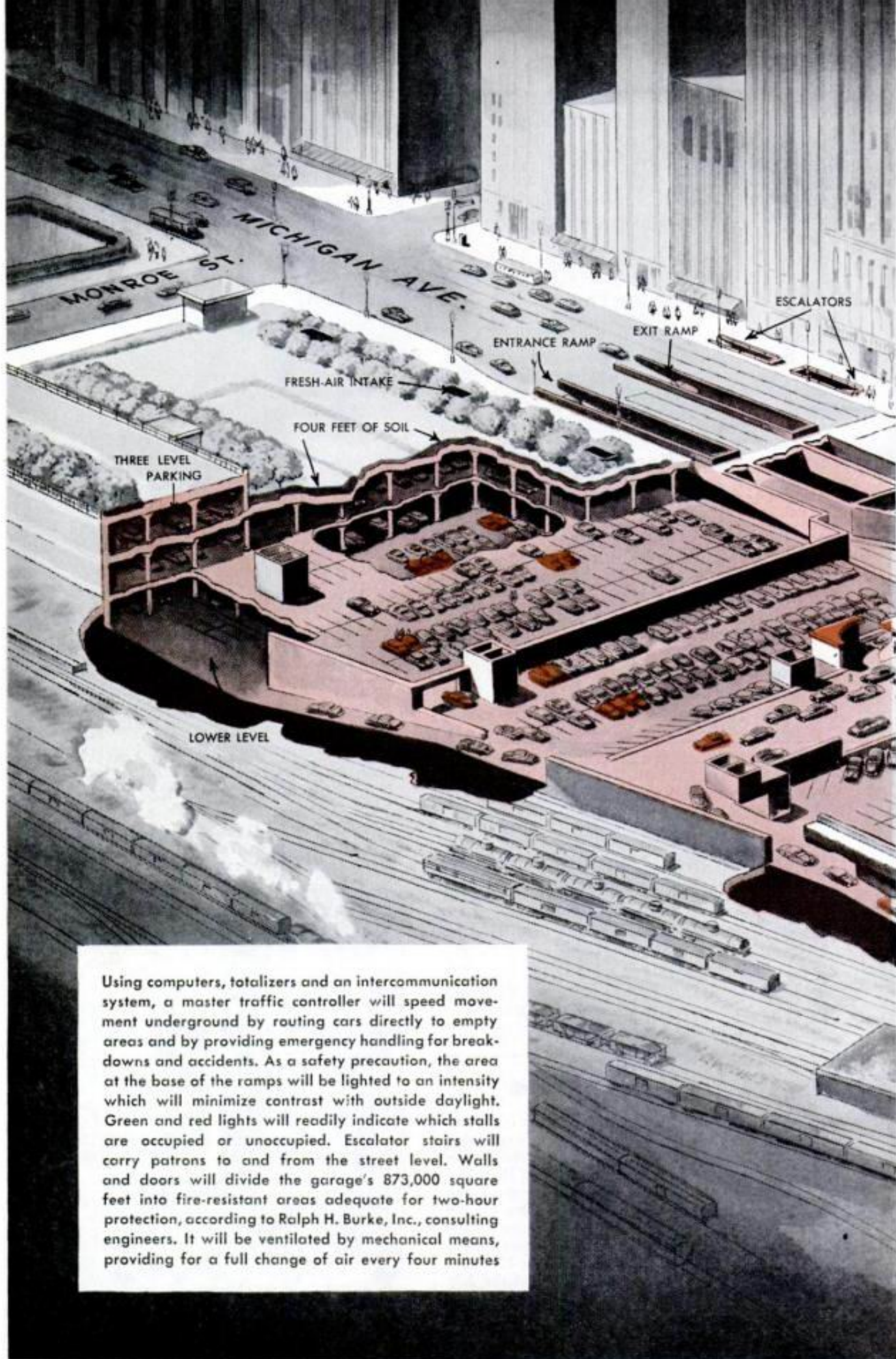
NAVIGATOR

FLIGHT DECK

MORE THAN 100 PASSENGERS will be able to fly through the stratosphere between London and New York in five to seven hours in a jet liner to be built in England. It will cruise at more than 600 miles per hour. Called the Avro Atlantic and scheduled for completion in 1958, it is a development of the Avro Vulcan bomber now being built for the British Royal Air Force. Its delta-wing design will put the exhaust ends of the four turbojet engines, where the noise level is highest, well behind the rear passenger seats. All the passenger seats will face the rear, an arrangement recommended by many safety experts. With the entire fuselage pressurized to nine pounds per square inch, the cabin "altitude" will be only 8000 feet when the airliner is flying at 45,000 feet. A luxury version of the Atlantic, with all seating two abreast, will carry 76 passengers, while a tourist model of the huge plane will comfortably accommodate as many as 113

G. H. JAYES

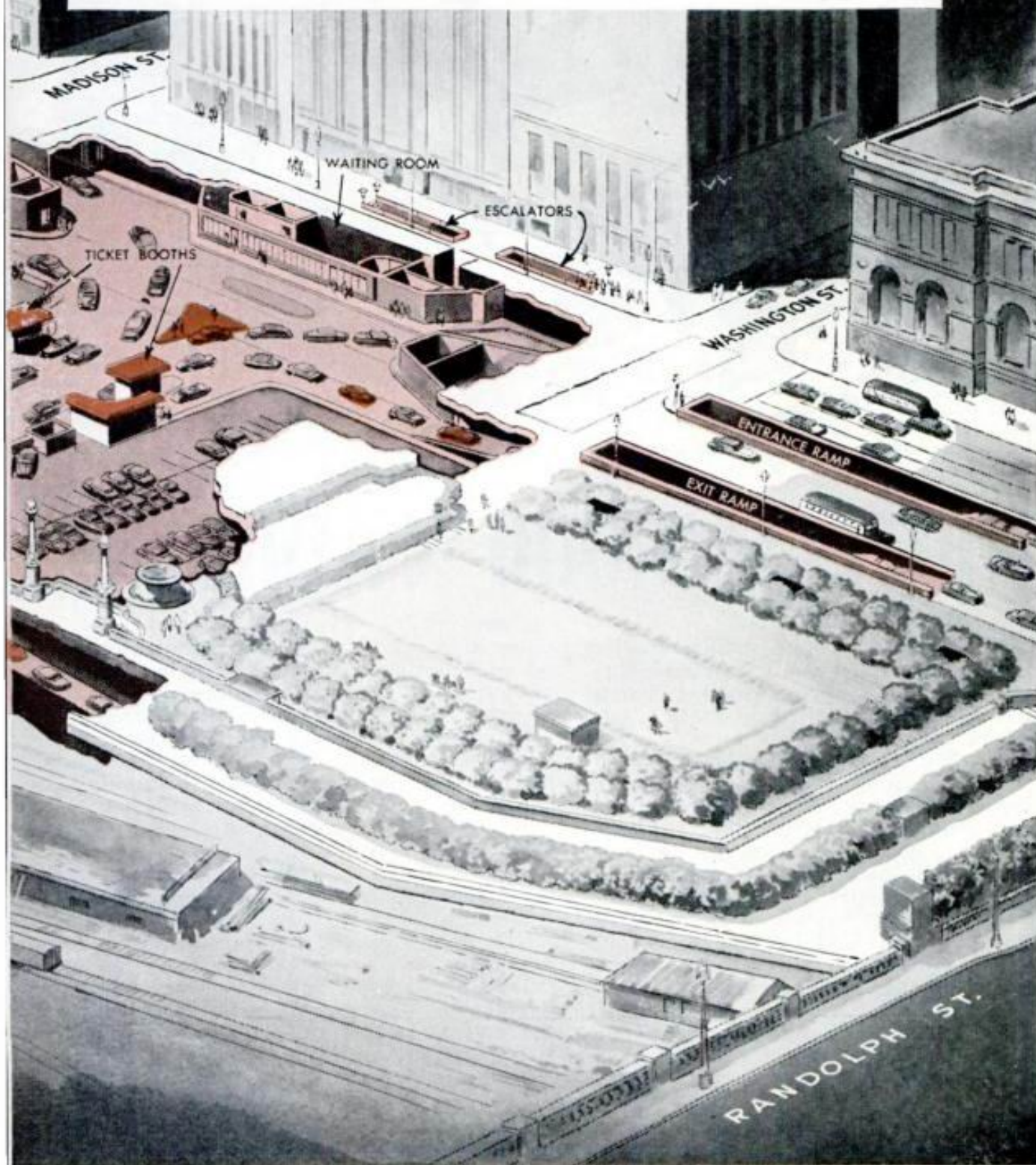




Using computers, totalizers and an intercommunication system, a master traffic controller will speed movement underground by routing cars directly to empty areas and by providing emergency handling for breakdowns and accidents. As a safety precaution, the area at the base of the ramps will be lighted to an intensity which will minimize contrast with outside daylight. Green and red lights will readily indicate which stalls are occupied or unoccupied. Escalator stairs will carry patrons to and from the street level. Walls and doors will divide the garage's 873,000 square feet into fire-resistant areas adequate for two-hour protection, according to Ralph H. Burke, Inc., consulting engineers. It will be ventilated by mechanical means, providing for a full change of air every four minutes

Chicago Builds a Three-Story Underground Garage

THREE BLOCKS of Chicago's lake-front park and a like section of its most heavily traveled street are temporarily uprooted as the city digs its first underground garage. The three-level subterranean building will accommodate 2359 automobiles. Cars using it will stream directly into and from traffic on Michigan Avenue over four ramps kept snow and ice-free by radiant-heating panels. After parking tests by nonprofessional drivers, the storage bays were built 27 feet wide for three cars and the aisles made 22 feet wide. After completion of the garage next year, Michigan Avenue and Grant Park will be restored approximately four feet above the roof of its upper level. ★ ★ ★

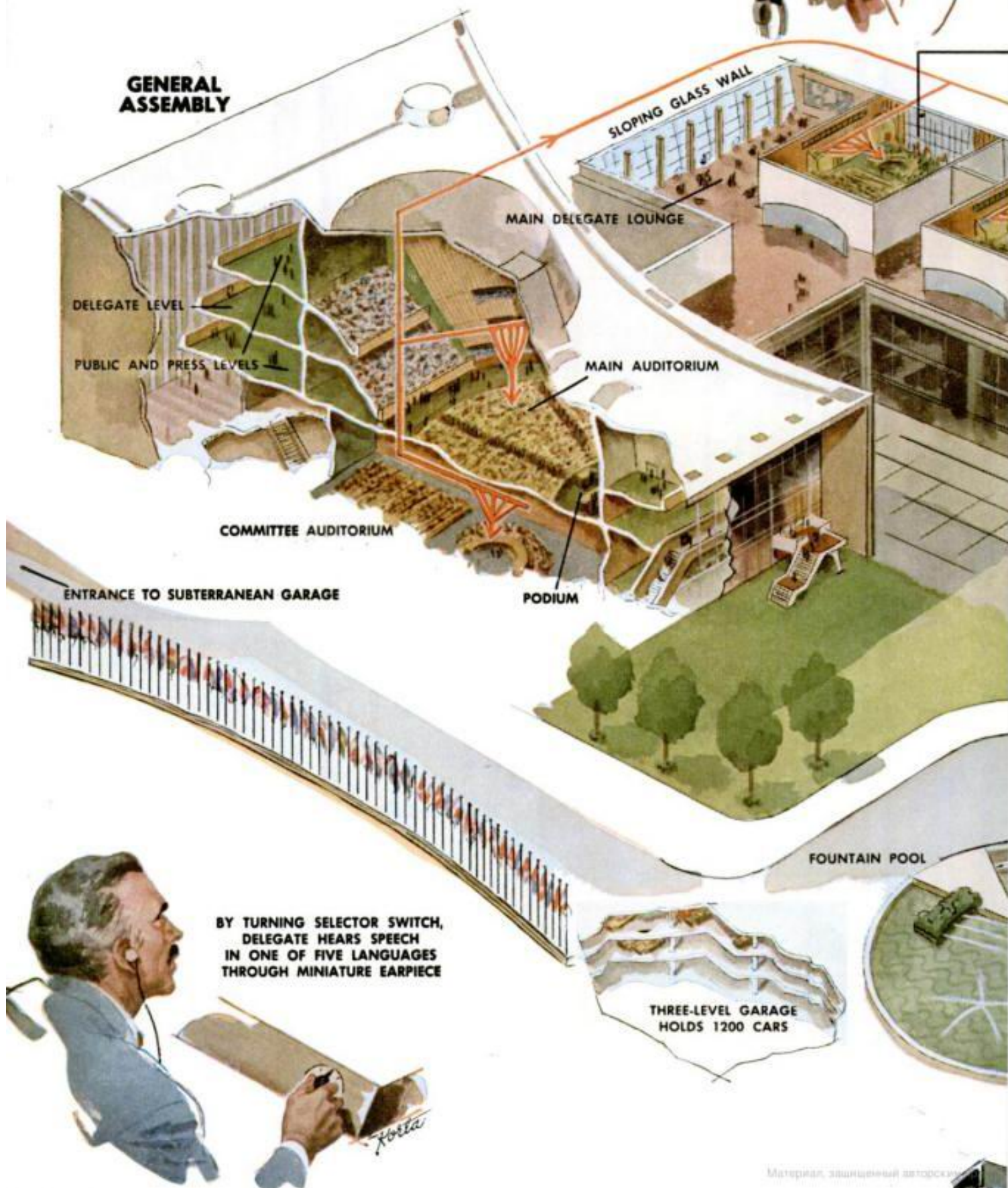


Headquarters for the world consists of three main buildings plus a library. Built on an 18-acre site along New York's East River, the "city within a city" cost \$67,500,000. An international team of architects and engineers designed the buildings. One of the many unique features is the electronic system, shown in red below, which permits any speech or debate to be broadcast in five languages simultaneously, and received almost anywhere in the three big buildings. Reporters can dial any of the conference rooms and receive speech then in progress

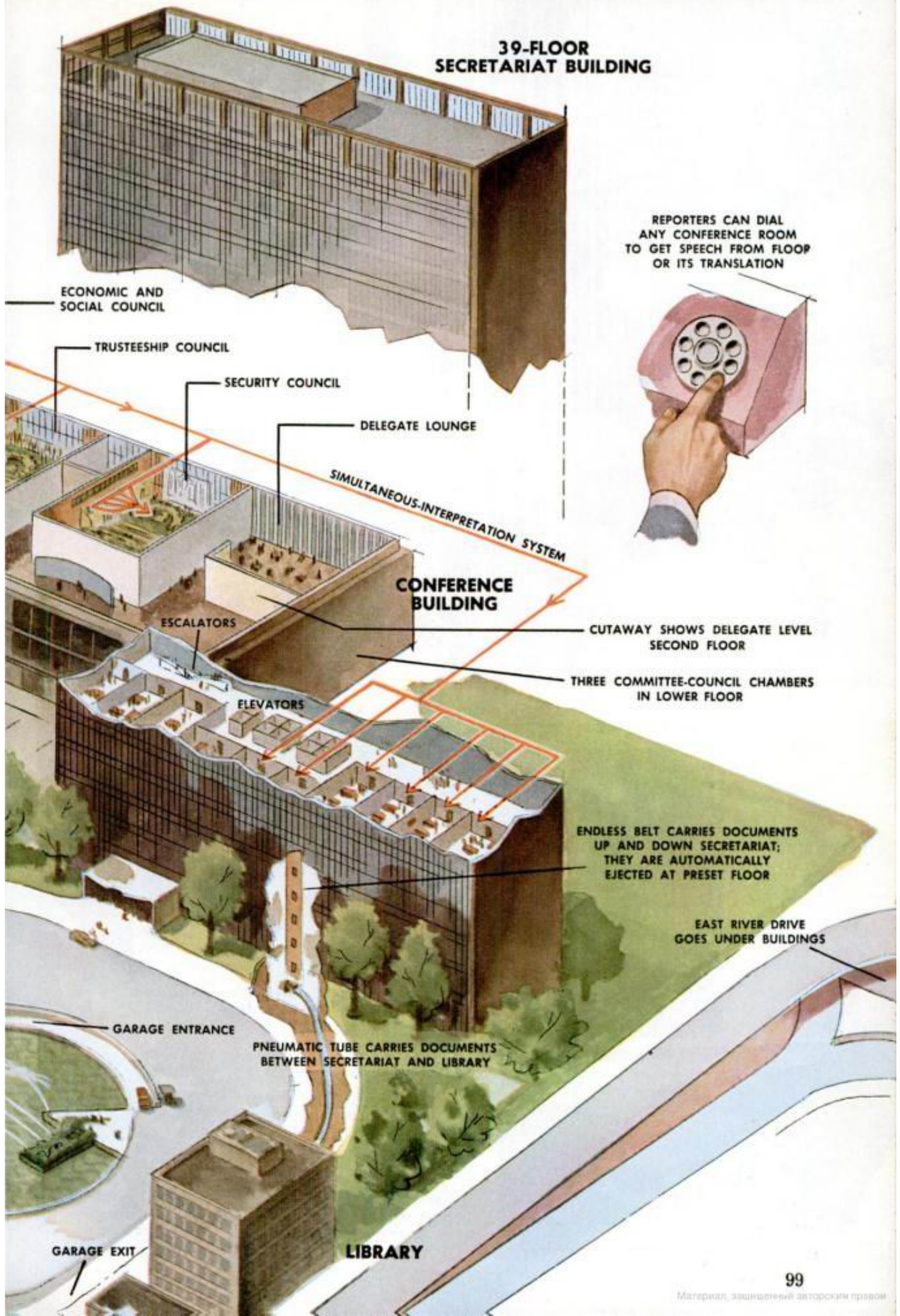
FIVE INTERPRETERS BROADCAST TRANSLATIONS OF SPEECH



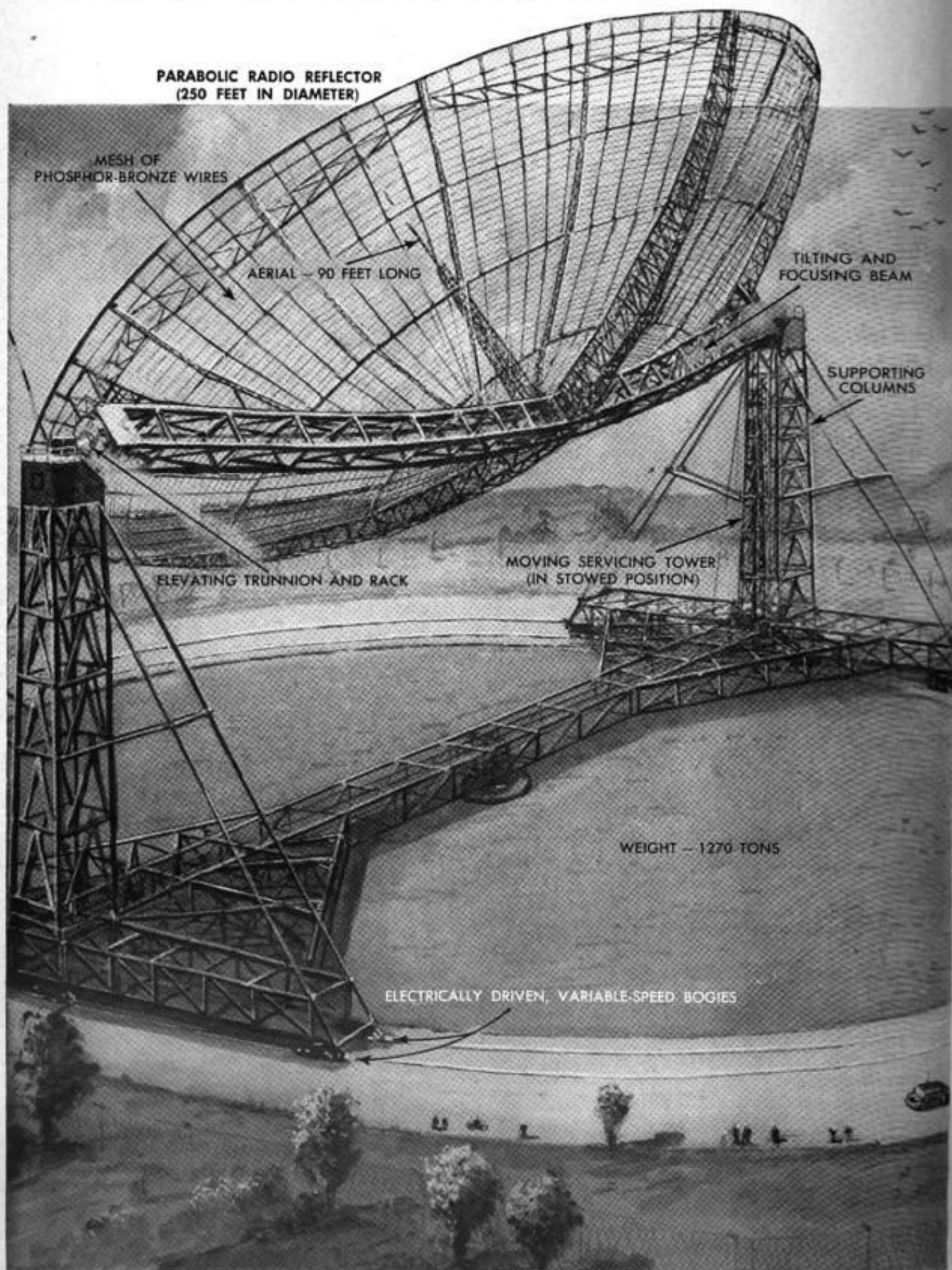
GENERAL ASSEMBLY

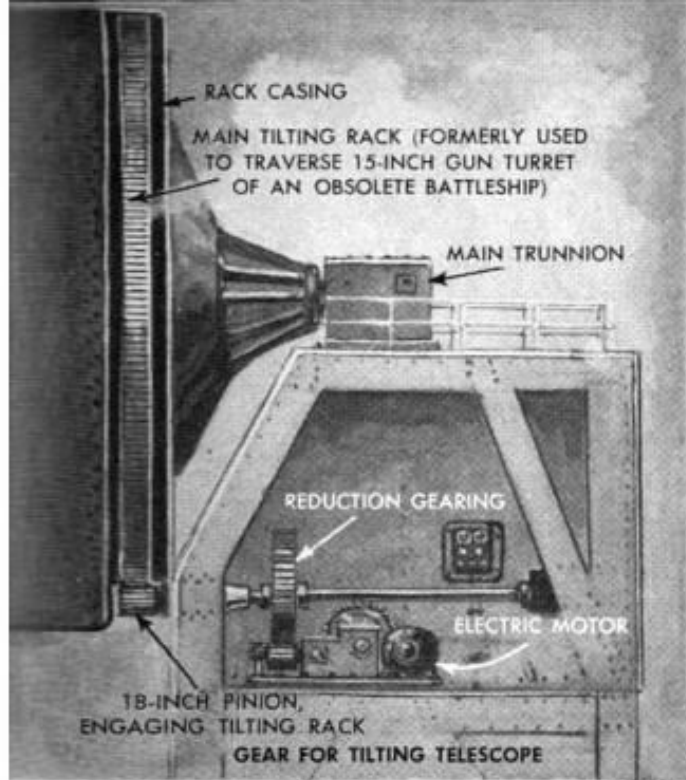


39-FLOOR SECRETARIAT BUILDING



GIANT RADIOTELESCOPE MAPS UNEXPLORED SKIES





Drawn especially for Popular Mechanics by the British Illustrator, G. H. Davis

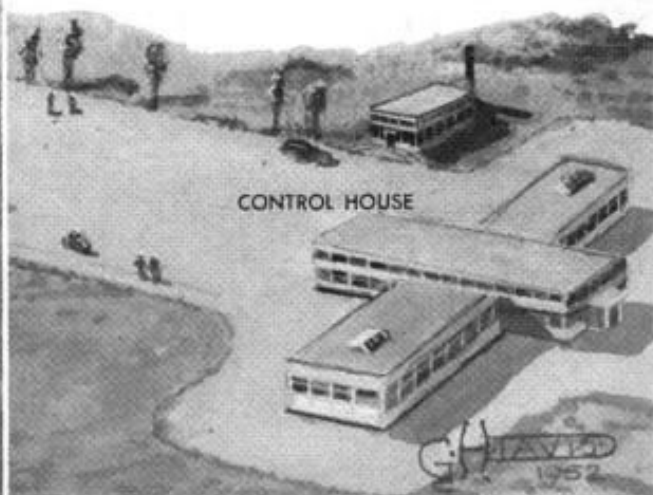
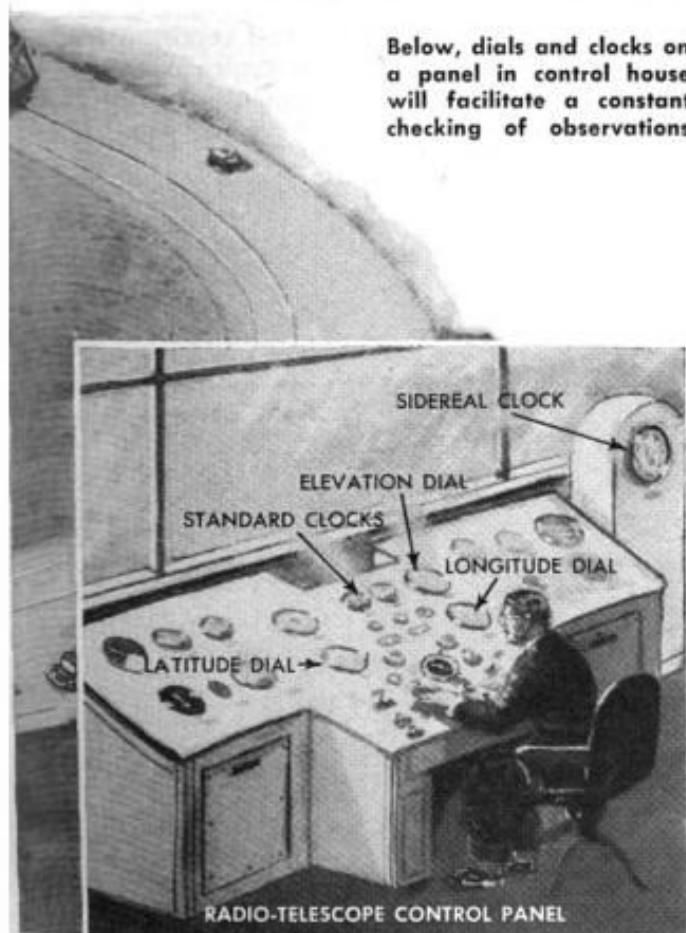
Precise gearing, left, controls reflector's movements. Right, radar and cameras will record the observations

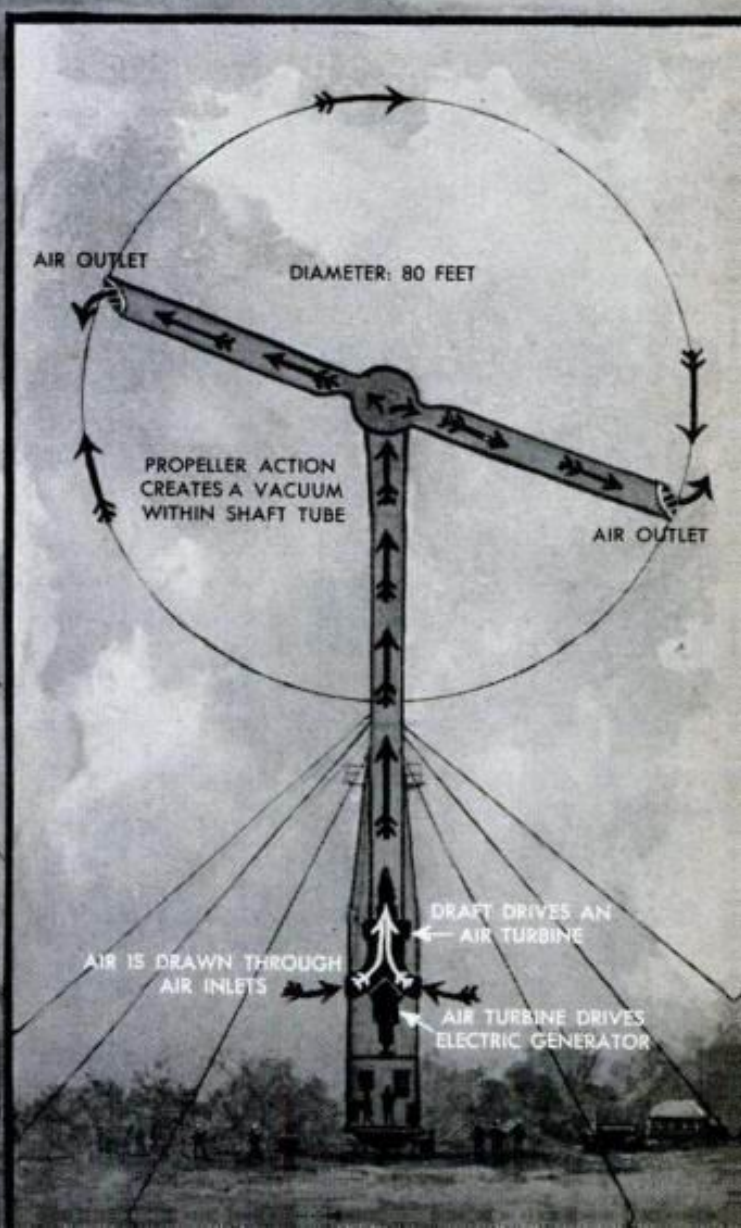
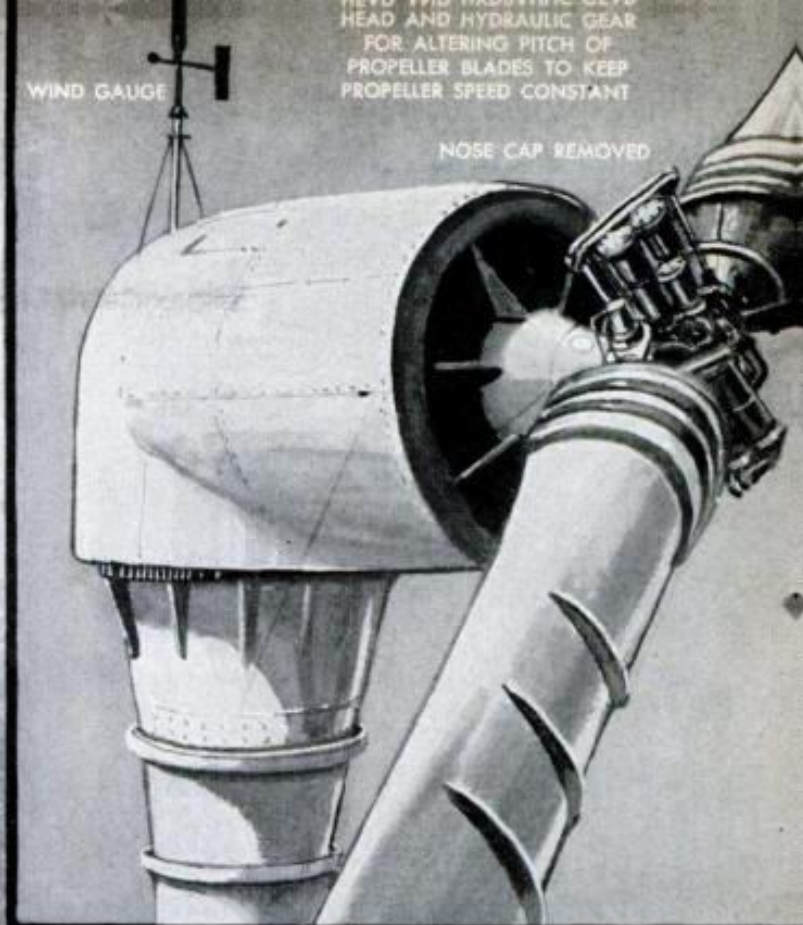
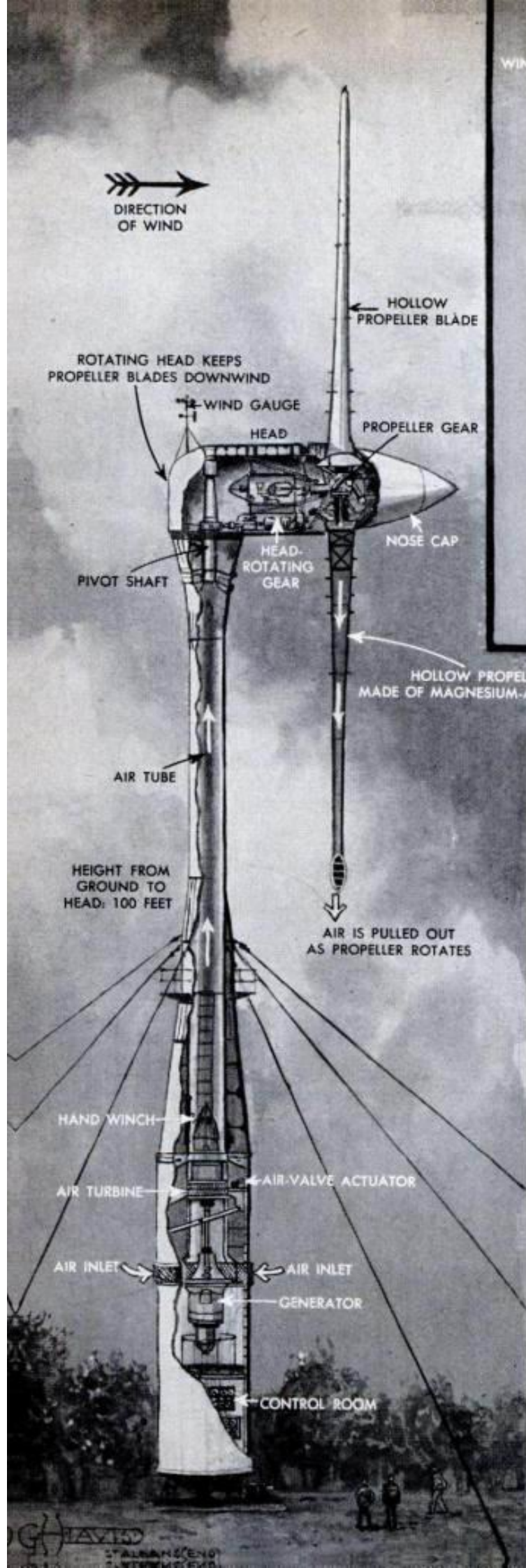
DISCOVERY OF STARS over 750,000 light-years away is expected with the completion of a giant, rotating radiotelescope being built in England. A smaller, fixed instrument, probing nearly that far, has already detected about 100 additional stars. Shaped like a huge electric fan, the new telescope will be 250 feet in diameter, weigh 1270 tons and will rotate on a platform mounted on 185-foot elevating racks. A 90-foot aerial

will extend out from its center. The reflector itself will be a web of phosphor-bronze wires one tenth inch in diameter, supported by a metal framework. The aerial will send out short pulses of energy at regular intervals. If they strike against a distant star or other solid body in space, a small amount of incident energy is scattered and a radio "echo" is returned to the station where it is received and amplified. Since the angle at which the radio wave was transmitted and the speed at which it travels will both be known, the star's location can be fixed by the elapsed time between the sending and receiving of the signal. The telescope is automatically controlled by a clock that enables it to be trained constantly at any particular point in space, despite the earth's movement.

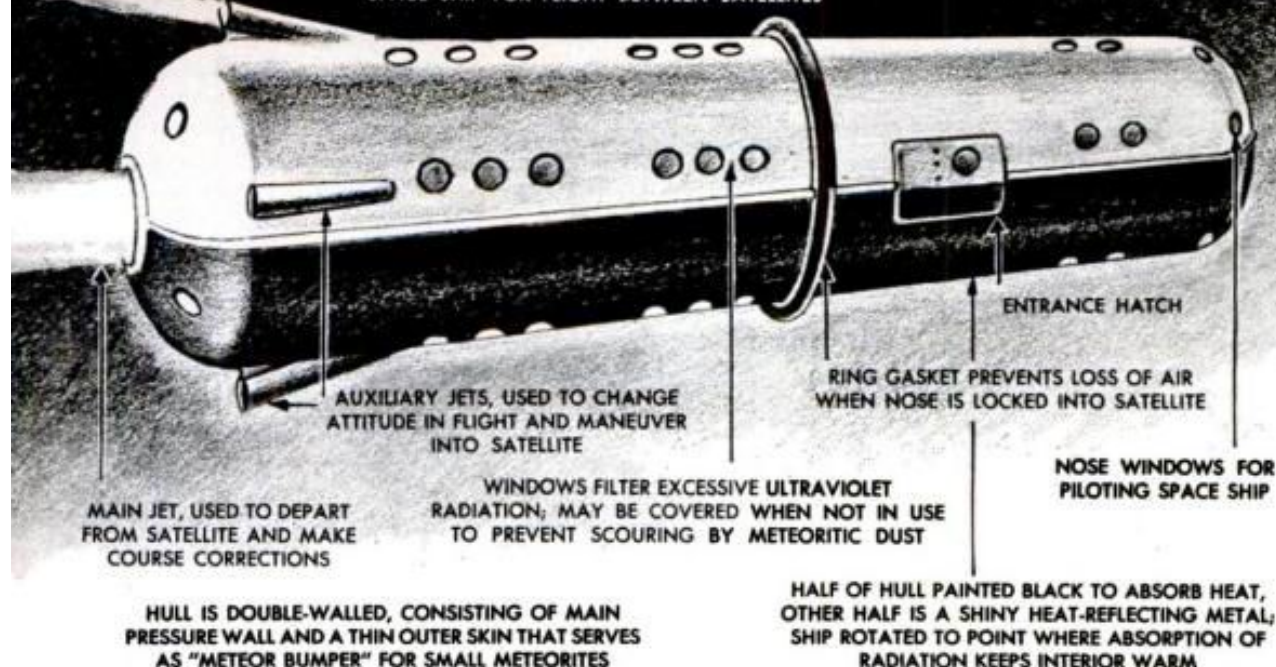
A solid reflector was believed impracticable because the aerial probably would melt from the sun's heat reflected on it by a metal bowl, and wind and snow would overtax the structure's strength. ★ ★ ★

Below, dials and clocks on a panel in control house will facilitate a constant checking of observations





SPACE SHIP FOR FLIGHT BETWEEN SATELLITES



Artist's concept of space ship is a huge cylinder. Streamlining would be of no value in frictionless space

broken apart or shrunk to about the size of earth to provide a comfortable surface gravity. It would have to be endowed with a useful atmosphere. Finally, it would have to be moved closer to the sun, at about earth's orbit, where it could absorb enough solar radiation for our needs.

These are fantastic ideas, but are they absurd? Not necessarily, Professor Zwicky believes. He points out that unlimited power will be available when nuclear fusion is achieved and that no fundamental principle seems to stand in the way of using nuclear fusion on a large scale. (Fusion is the combining of light elements into heavier ones, as is done in the sun, in contrast to the present nuclear-fission processes in which heavy atoms are split into lighter ones.)

With nuclear fusion, he continues, it should be possible to create and control a jet that would approach the proportions of those produced in minor stellar eruptions. This would be the tool with which the planetary system would be juggled about. A tremendous lopsided jet on the surface of a planet could divert the body from its accustomed motion. Jets might also be used to decrease the mass of the planet or to increase the masses of its satellites.

Professor Zwicky's conclusions arise from what he terms "morphological thinking," the orderly listing of all possible solutions to a given problem. Most devices and processes in the past were invented helter-skelter, he asserts, and yet nothing can be thought of that is not already waiting for us in the morphological box. Instead of attacking a problem haphazardly, it is wiser to state the problem formally and then to consider all possible solutions not prohibited by the laws of nature.

One might confidently start work tomorrow on the theoretical and mathematical problems of rebuilding the planetary system, the Caltech astrophysicist says, since enough knowledge is available to guarantee that very little of the work will be found later to have been done in vain.

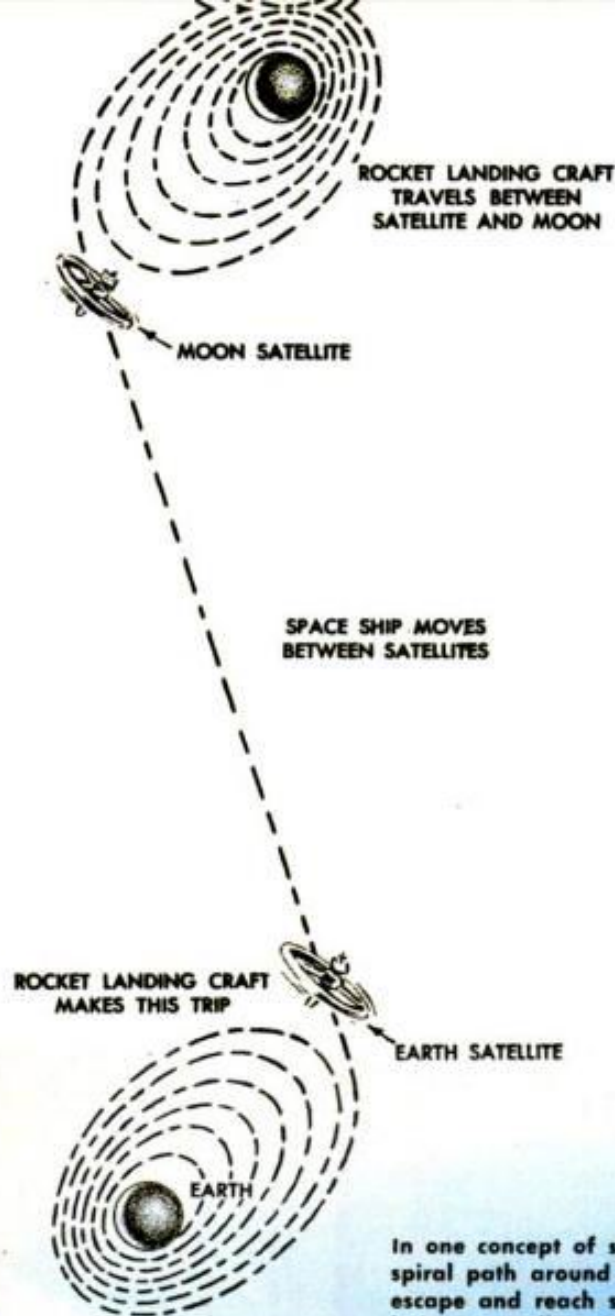
"However, there is one danger," he declares. "Through poor handling of the operations, or maliciously, the earth itself might be exploded. We must be concerned with the stabilization of large bodies against nuclear fusion as well as with the processes of ignition."

Several centuries may elapse before mankind is ready to test Professor Zwicky's proposals; long before then, many scientists are convinced, we'll be able to fly regularly to the moon and will have explored Mars and Venus. One of these feats may be accomplished during the next 50 years. Today hundreds of research workers in this country alone are engaged directly or indirectly in solving the highly involved problems of astronautics.

Research on long-range military rockets has yielded much information about propellants and power plants suitable for space flight. The principles of astrogation, or space navigation, have been worked out by astronomers. Study is being given to "canned air" and the other problems of living in empty space. The scouring of meteoritic dust on windows and the graver hazards of heavy primary cosmic-ray radiation and collisions with meteors are subjects of research.

Even the legal aspects of laying claim to celestial bodies have been discussed.

One of the phenomena to which space travelers will be subjected is weightlessness,



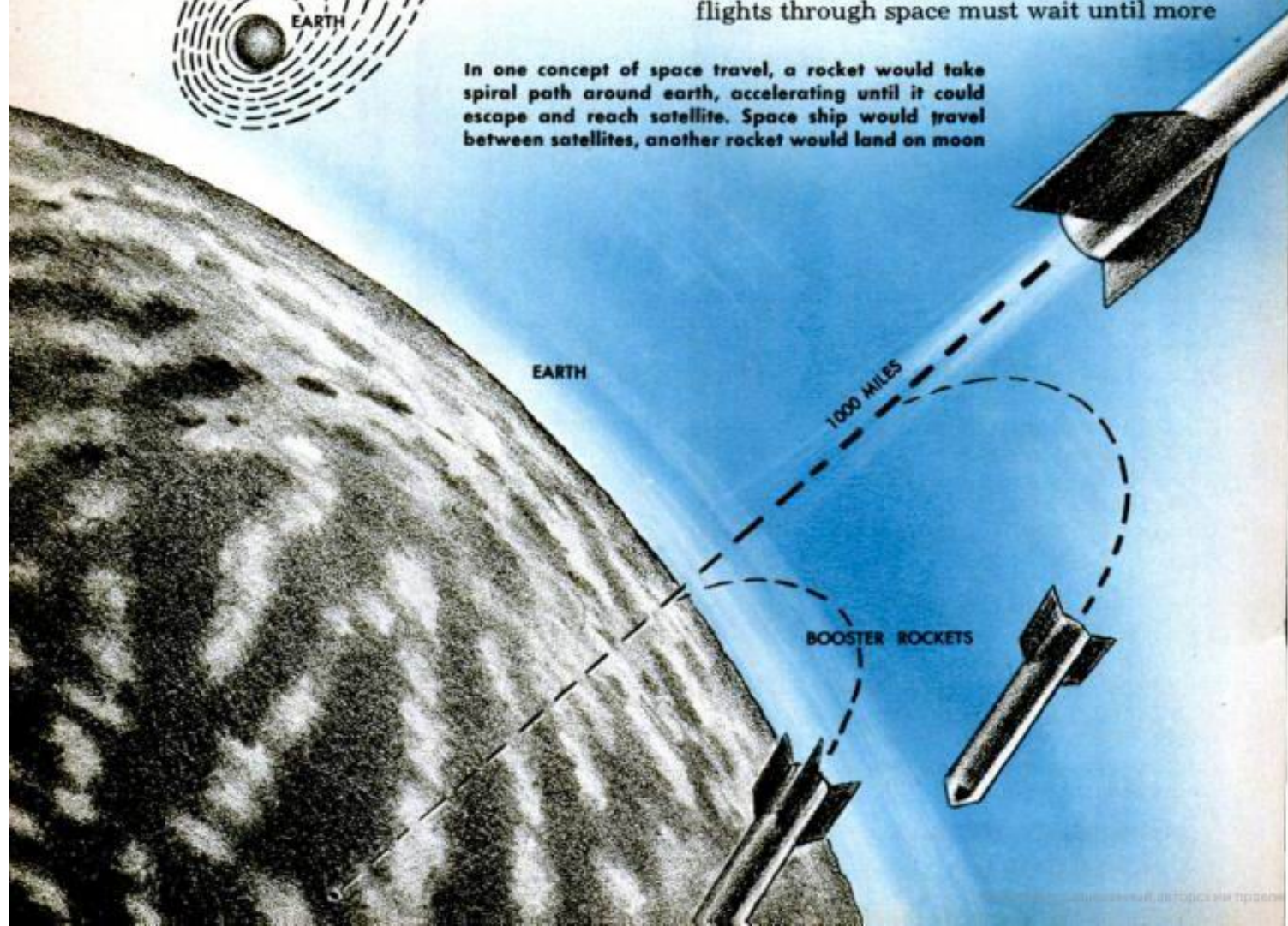
In one concept of space travel, a rocket would take spiral path around earth, accelerating until it could escape and reach satellite. Space ship would travel between satellites, another rocket would land on moon

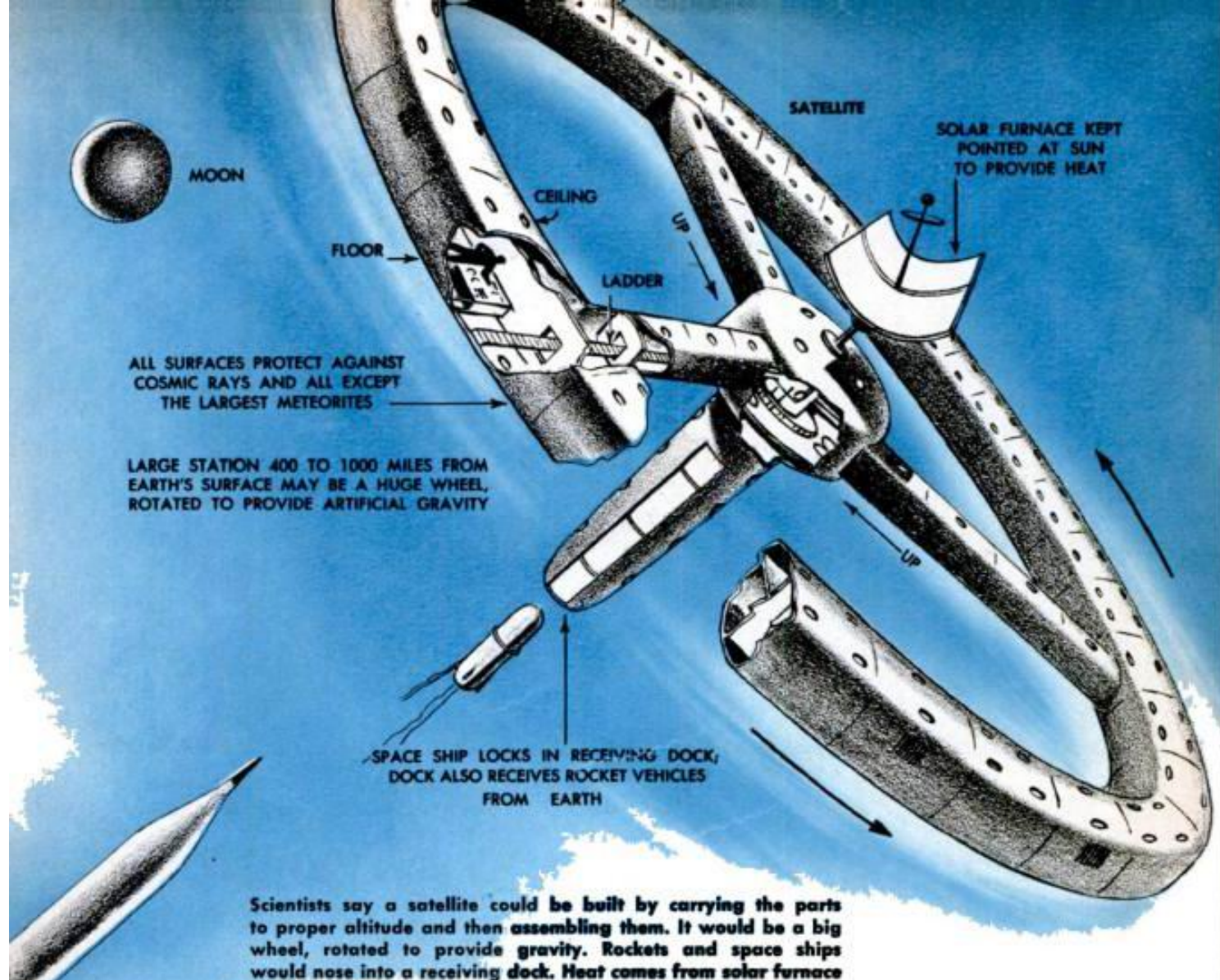
a condition now engaging the special attention of the space-medicine division of the Air Force School of Aviation Medicine at Randolph Field, Tex.

"Zero gravity will give one the sensation of falling into a bottomless pit, no matter how tightly he holds on to his seat," a member of the space-medicine team remarks. "A sudden transfer to the gravity-free state will not be recommended for weak souls, though one may count on a gradual adaptation to the strange sensation of being in a perpetual fall."

Weightlessness is a far more serious condition than might be supposed. The space-medicine scientists are concerned, among other things, about the possibility that a person in a gravity-free state would suffocate in his own breath. There would be no circulation of air in a room that has zero gravity; hence after a person had expelled a few lungfuls of air, he would be rebreathing his own exhaust gases. Some kind of forced circulation would have to be provided, not only for humans but for such devices as heat exchangers.

It would be possible today to build an unmanned step rocket that would escape from earth, never to return, or to shoot a few people in an ionocruiser to an altitude of 200 miles, from which height the winged rocket could glide slowly back to earth. Even an unmanned rocket that could crash-land on the moon is a marginal possibility with today's knowledge. But round-trip flights through space must wait until more





efficient propellants have been developed.

To escape from earth a rocket must move at the rate of 25,000 miles per hour, about five times the speed attained by the nose section of one of the bumper rockets fired at White Sands Proving Ground. The speed of escape from the moon is a mere 5300 miles per hour because of the smaller size of that body.

The theory of space travel is based on the idea that after a rocket gets away from earth it would continue to travel at its escape speed without the use of power. It would become a celestial body whose path and ultimate speed would be governed by the pull of the sun and planets. To reach a particular target, such as the moon, it would be necessary to fire the rocket at a predetermined time in a certain direction.

Professor Zwicky suggests that chemical energy for attaining escape speed may be found in the excited atomic particles that exist high in the earth's exosphere. If these could be utilized in a ductlike motor it might be possible to drive a rocket at greater and greater speeds as it circles the earth, finally escaping into space without discomfort from high accelerations. Until we learn differently, he concludes, there

is even the possibility that space itself contains some form of energy or matter that could be used for propulsion. This would greatly simplify solving the problems of navigation.

Present research on power, however, is along orthodox lines. An atomic power plant might be one solution, although by itself this energy would not be sufficient. Anthony J. Nerad of the General Electric Research Laboratory suggests that an efficient propellant may be found in the metallic hydrides. These compounds contain large amounts of hydrogen in chemical combination with a metal. Volatilized and expanded in some kind of motor, the hydrogen may prove much more efficient than any rocket propellant we now have.

Rocket scientists generally agree that we won't take off from earth and fly directly to such a destination as the moon. A trip like that would be made in three stages utilizing two transfer points.

Stage one would be the lift from earth to a satellite station possibly 1000 miles out. A rocket of moderate acceleration and probably conventional appearance might be used. Stage two would be the long trip

(Continued to page 224)

OVERBURDEN

CABLE WHEELS

COAL SEAM

DRIVING
GEAR

CUTTING-WHEEL CONTROLS

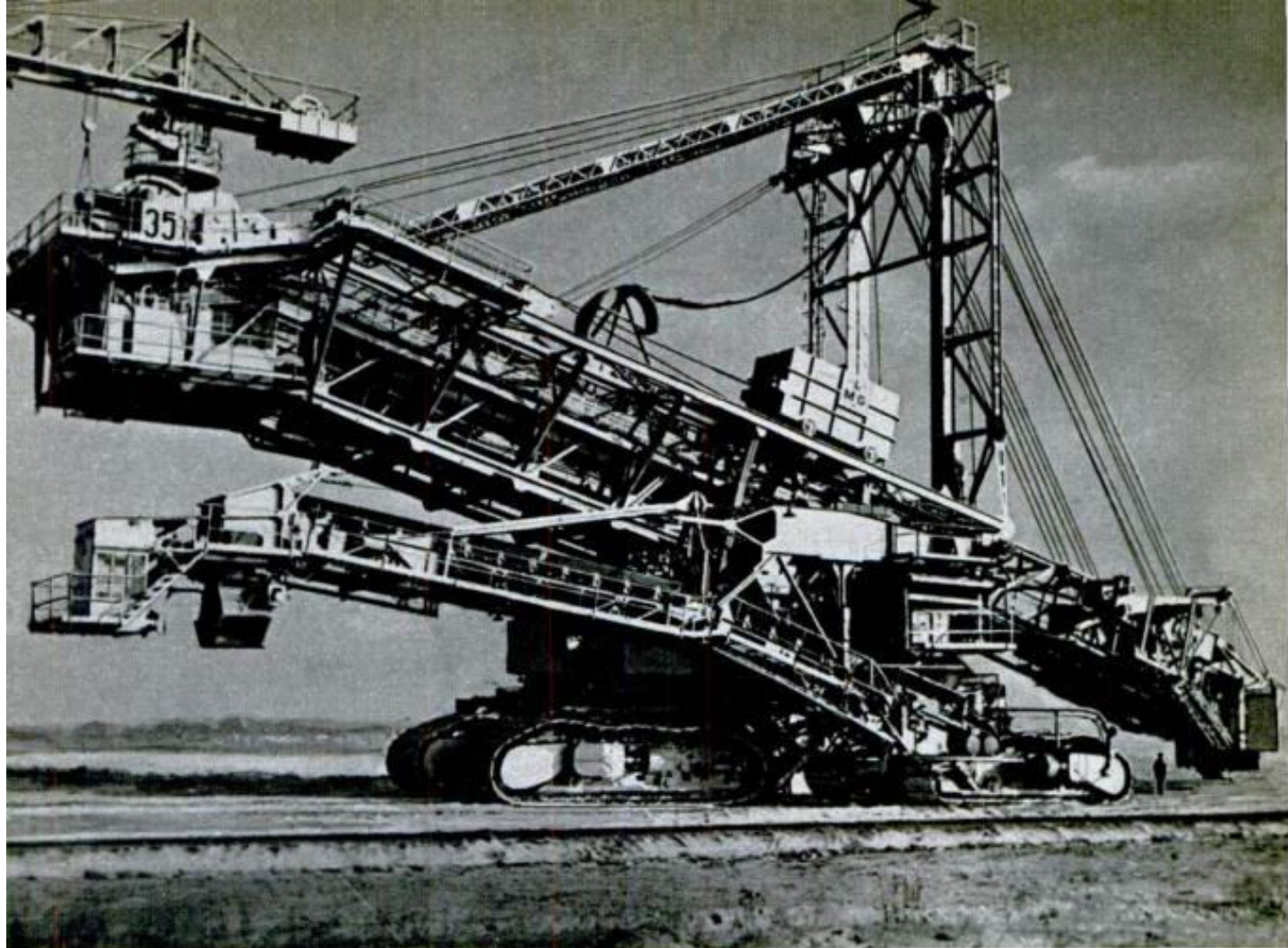
APPROX. DIA. OF CUTTING
WHEEL, 16 TO 18 FT.

Foreman directs operations as the excavator's giant cutting wheel, fitted with steel-toothed buckets, bites into coal seam

FOREMAN GIVES DIRECTIONS TO
CUTTER-WHEEL CONTROL BOX

G. H. JAVIS
HELMETEDT, GERMANY
1951

Материал, защищенный авторскими правами



"Walking" down road near Helmstedt, Germany, 1000-ton coal-digging monster displays its maze of girders

SIX-LEGGED BEHEMOTH MINES GERMAN COAL

By G. H. Davis

IN A MIGHTY PIT at Helmstedt, Germany, stands a gigantic machine created by a Leipzig engineering firm to increase the output of coal in that area.

As the 1000-ton monster slowly moves on its six enormous Caterpillar feet (each track is over seven feet wide and ten feet high), the whirl of its numerous electric motors fills the air. The giant cutting wheel at the end of a central arm of the machine eats into the coal seam, filling its steel-toothed buckets and dumping them on conveyor belts that carry the coal through the machine and deposit it from the rear-end hopper into waiting coal wagons.

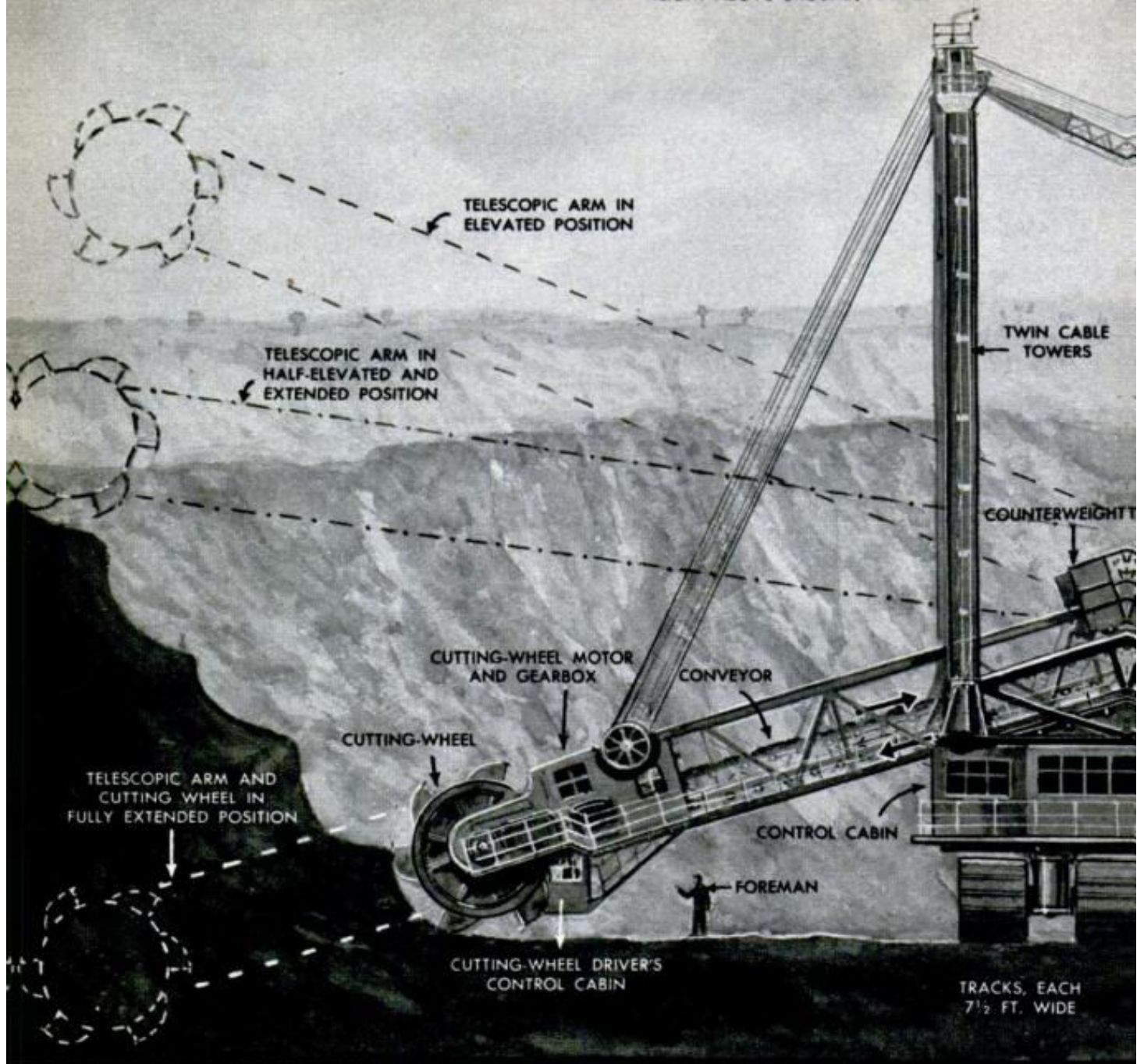
Located throughout the machine to drive all of its various working parts are 40 electric motors fed by a heavy electric cable that snakes along the coal floor of the pit from a commercial power supply.

Only three workmen are visible around

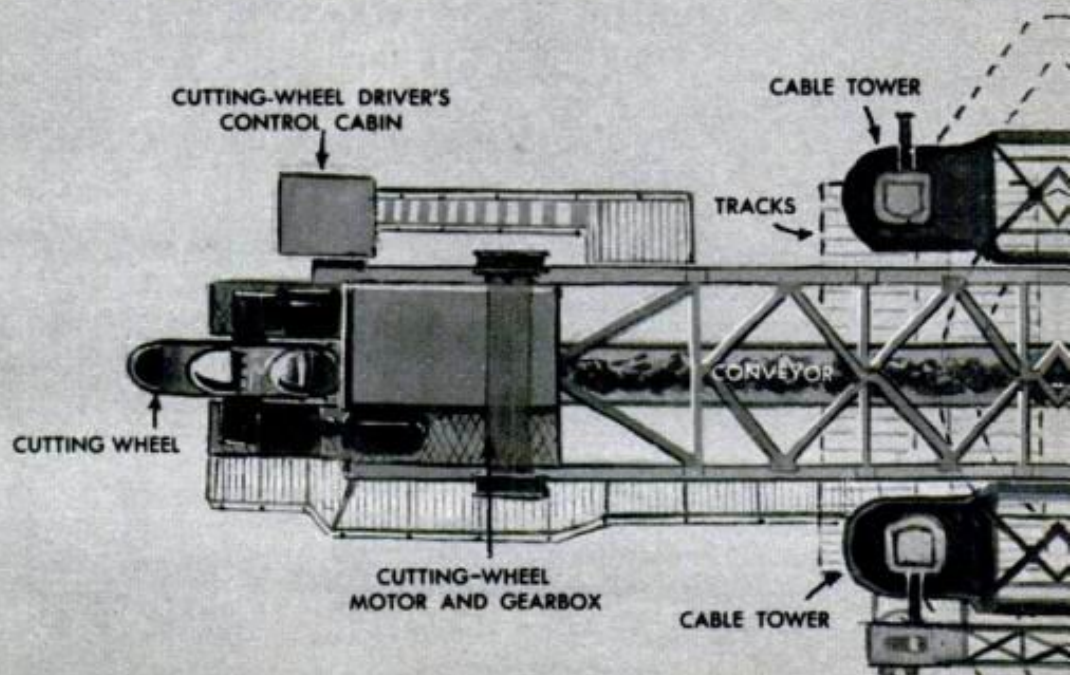
the giant digger when it is in operation: One sits in a forward cabin and controls the digging wheel; another, in a similar enclosure near the coal chute, controls the supply of coal to waiting cars, and a foreman watches the cutting and gives hand signals to the cutting-wheel controller.

As the excavator works along the coal face digging upward and sideways, the staggering weight of the machine exerts a pressure of seven pounds per square inch on the ground. It is only possible to realize the enormous size of the "walking" monster by standing near it and looking up at the towering, intricate latticework of girders that extends 86 feet into the air. From one end of the machine to the other, the over-all length is approximately 241 feet, with the telescopic arm in its retracted position, as illustrated in detail on the following pages.

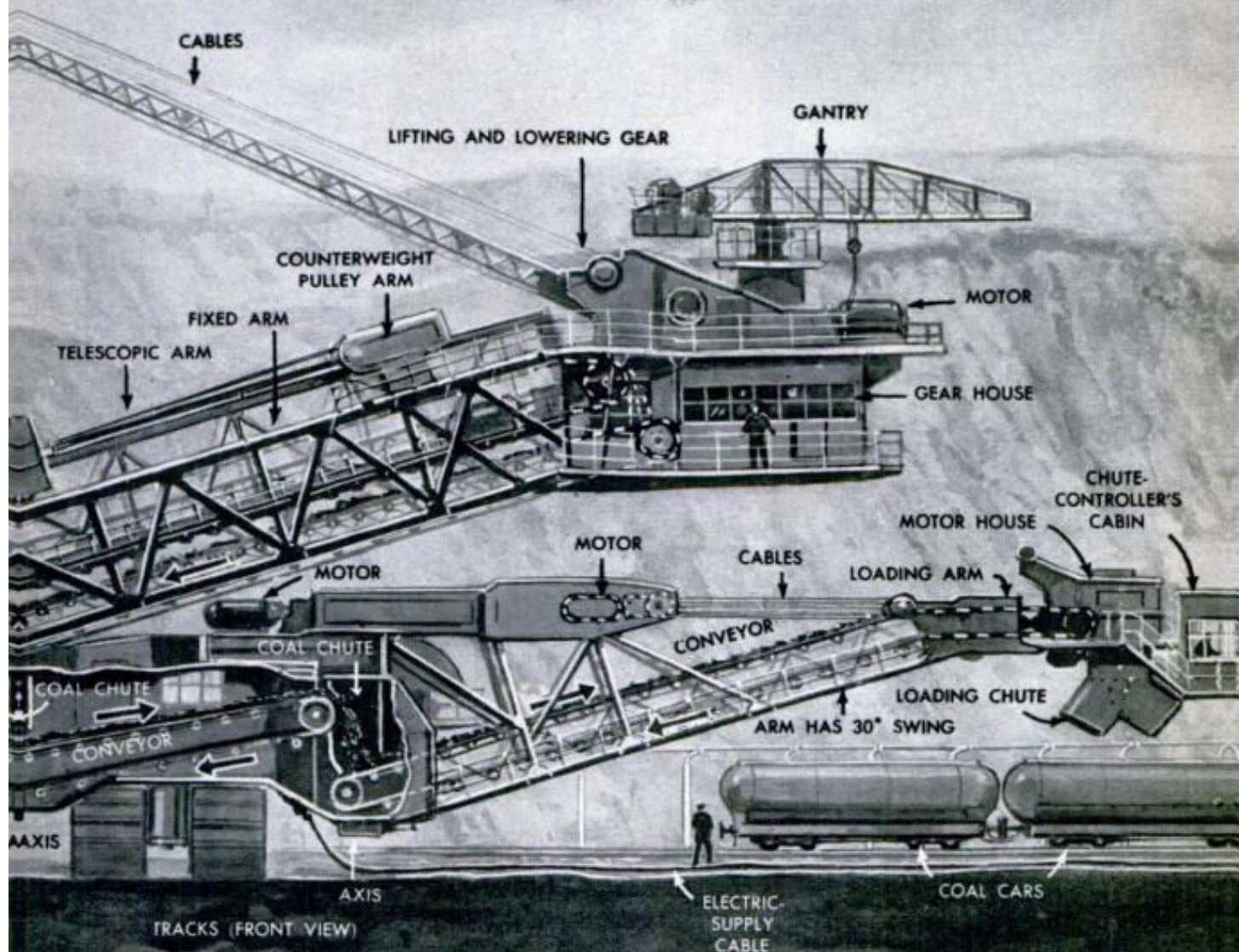
HEIGHT ABOVE GROUND, APPROX. 86 FT.



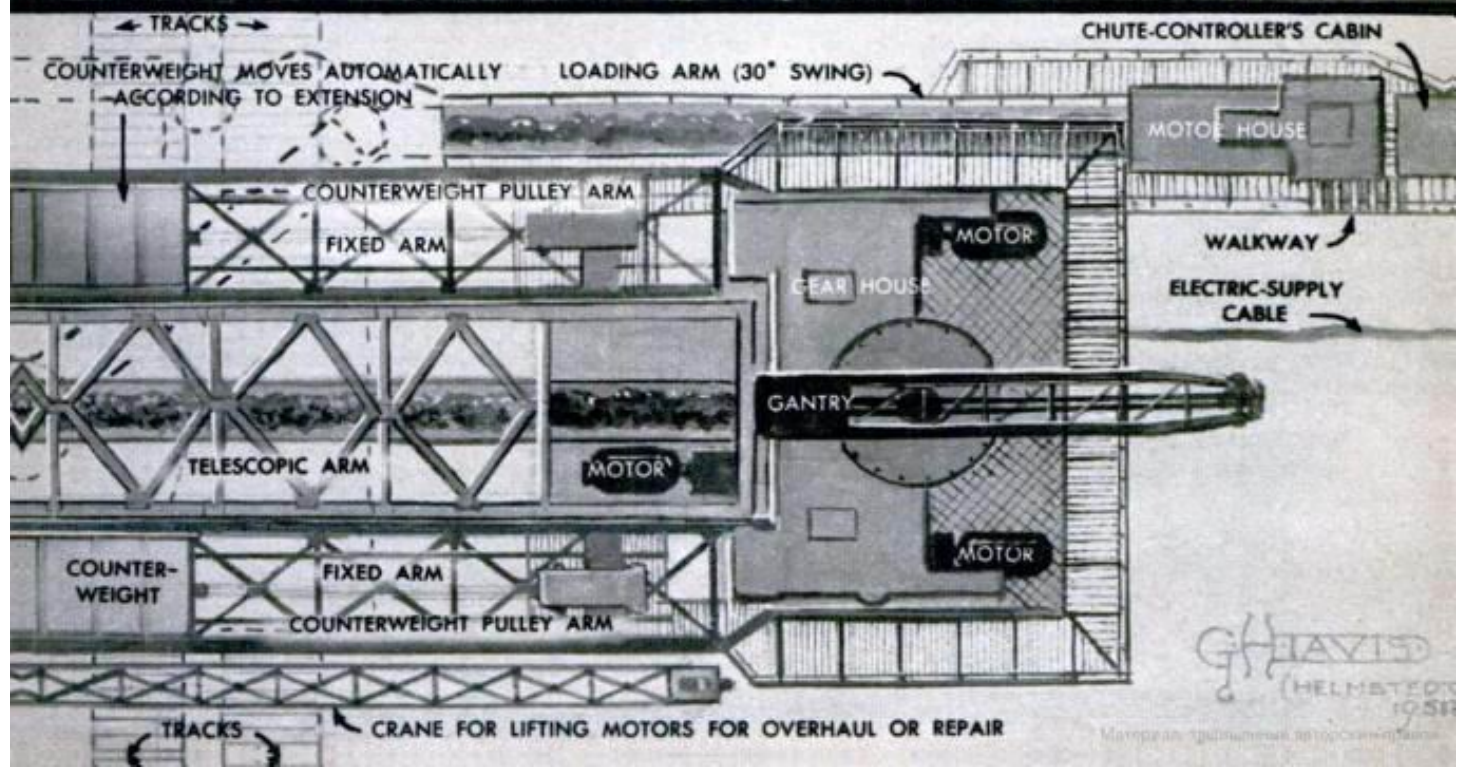
**PLAN VIEW
SHOWING
FIXED AND
TELESCOPIC
ARMS**



SIDE ELEVATION OF GIANT COAL EXCAVATOR AT HELMSTEDT, GERMANY



LENGTH OVER-ALL 241 FT. WITH ARM NOT EXTENDED

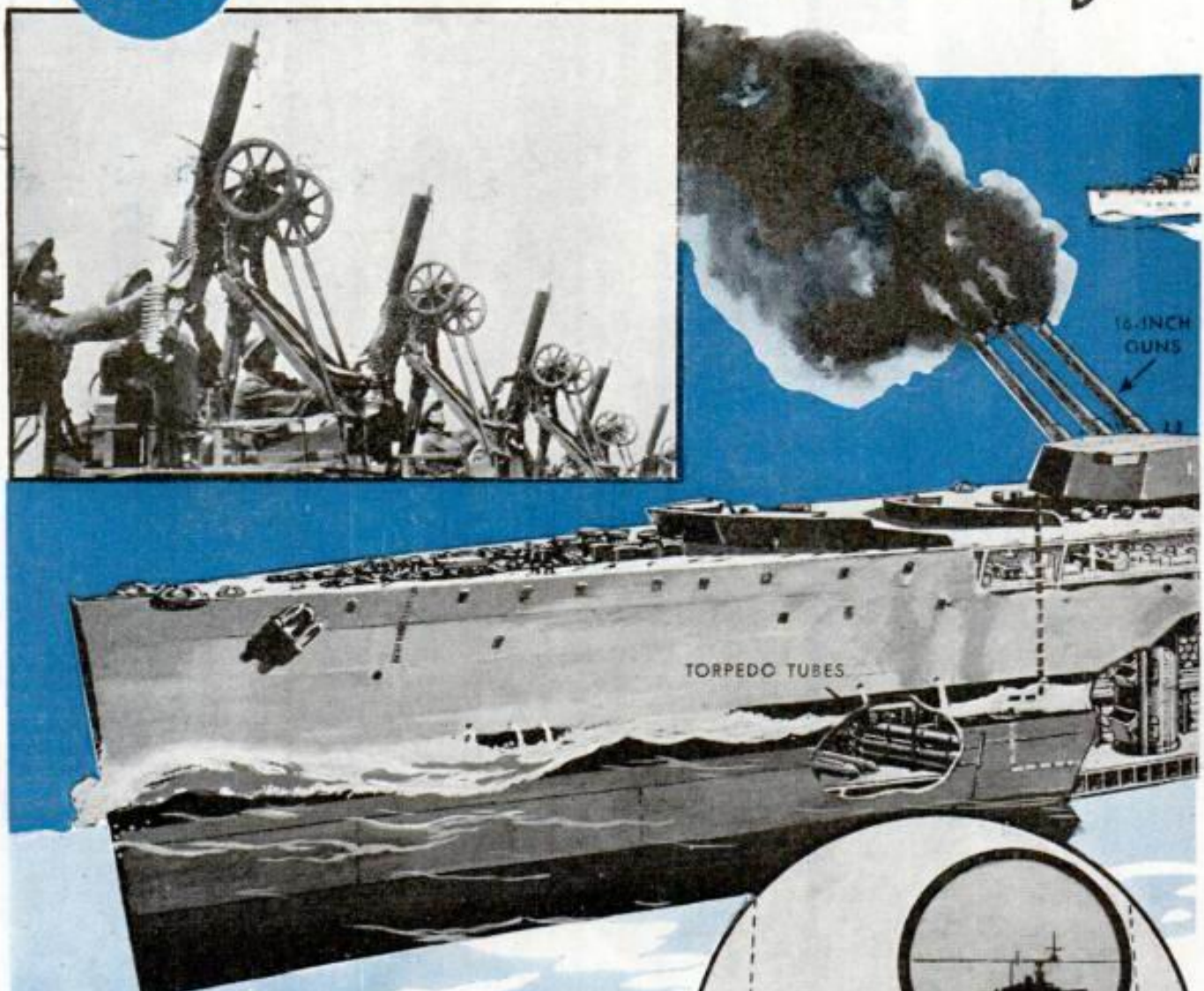


G. HAYES
(HELMSTEDT)
1958

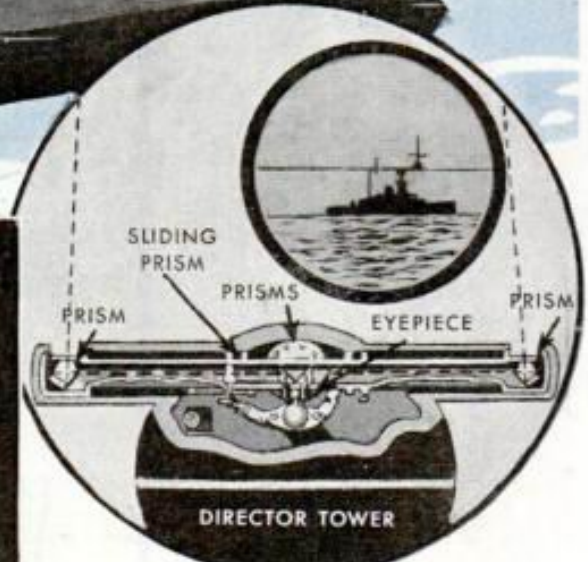
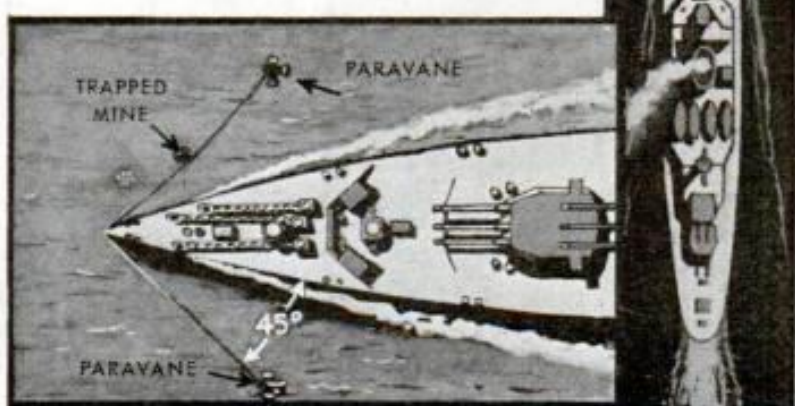
21053.

Soviet aircraft battery

The MECHANICS of



Mighty engines of warfare have been unveiled by nations involved in the new European conflict, as well as by countries that may be drawn into the struggle. Many, many anti-aircraft batteries, such as the one pictured at top of page, are found in Soviet Russia's red army



Bottom, left, how ship employs paravanes to avoid striking mines. Center, actual size of battleship as seen from bombing plane at 6,000 feet. Circle, above, diagram of range finder, with inset view of what it sees. When the two images coincide, the range is mathematically calculated with help of sliding prism

clerk

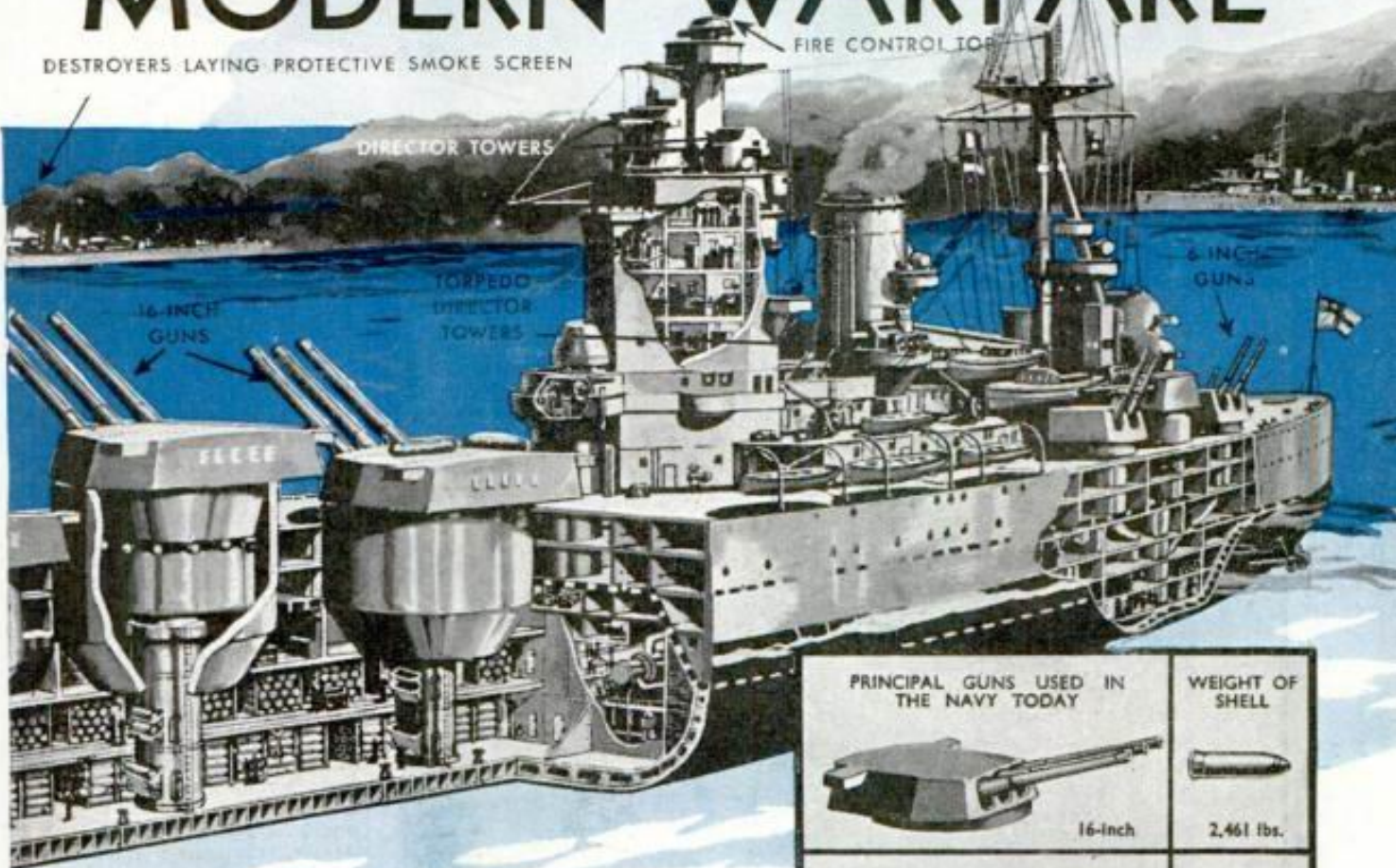
21053

MODERN WARFARE

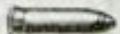
DESTROYERS LAYING PROTECTIVE SMOKE SCREEN

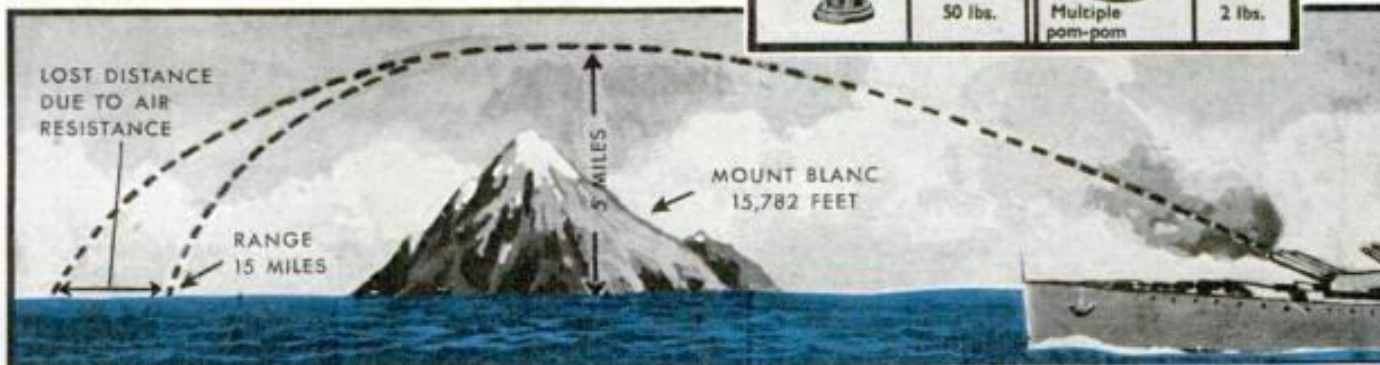
FIRE CONTROL TOWER

DIRECTOR TOWERS

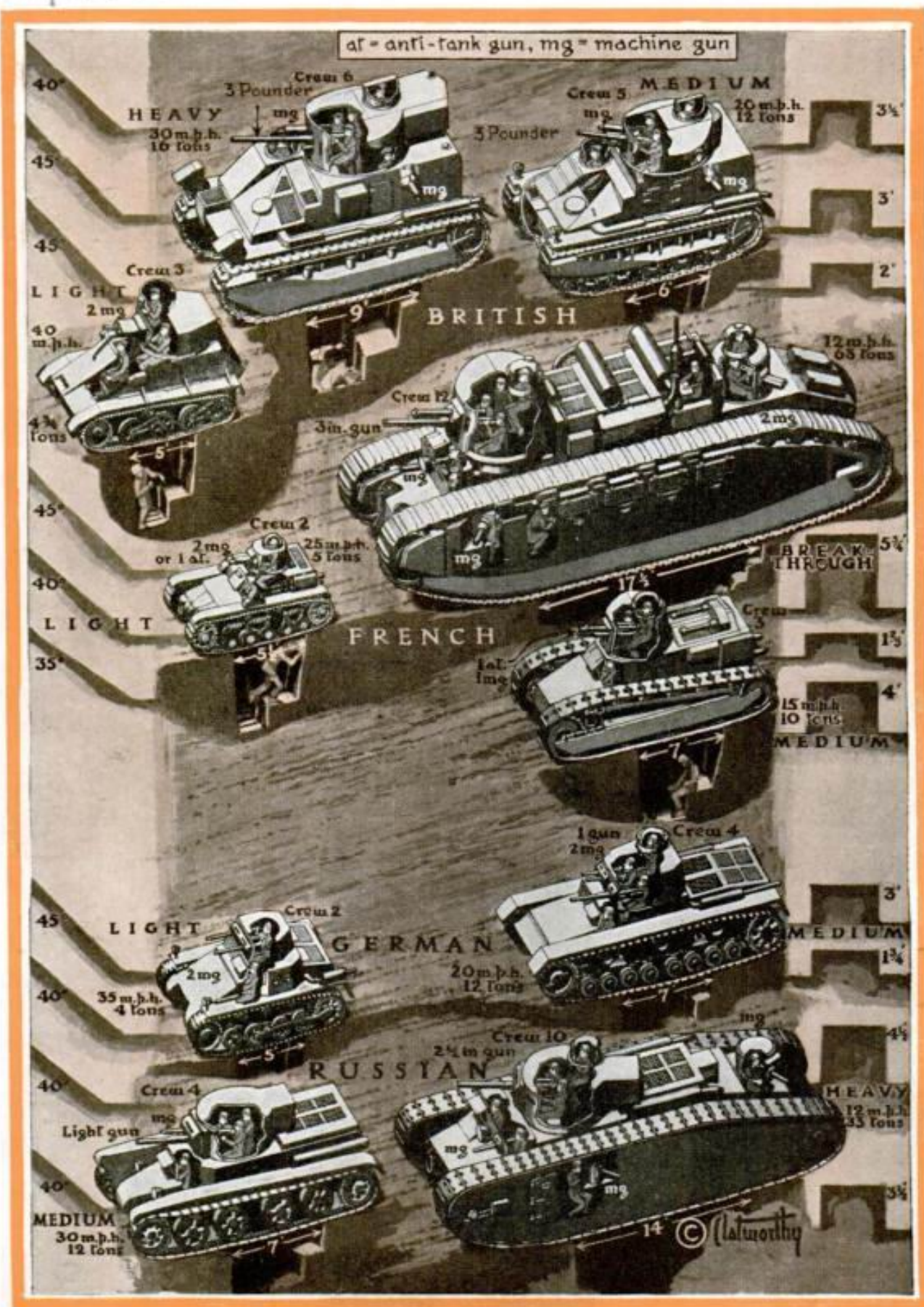
TORPEDO
DIRECTOR
TOWERS16-INCH
GUNS6-INCH
GUNS

How a mighty British battleship goes into action is shown on this and the page opposite. Decks are cleared and sixteen-inch guns firing, while destroyer lays protective smoke screen. Right, naval weapons and weight of shells. Bottom of page, range and trajectory of modern sixteen-inch naval gun and shell. The shell has a muzzle velocity of 1,800 miles an hour and a rate of fire of one round a minute. The sixteen-inch gun is the largest believed practical for warships to mount, under present methods of construction

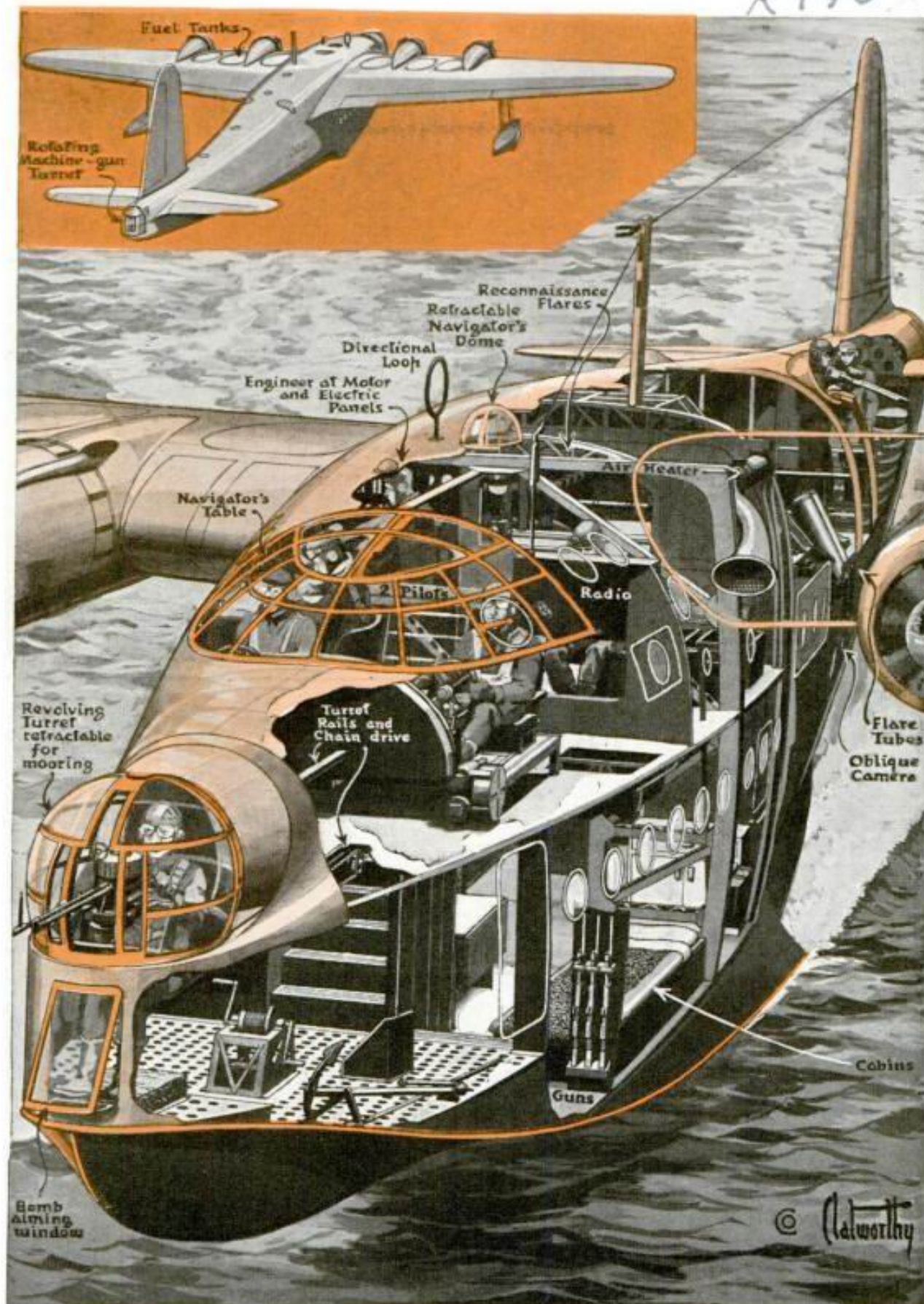
PRINCIPAL GUNS USED IN THE NAVY TODAY		WEIGHT OF SHELL	
	16-inch		2,461 lbs.
	15-inch		1,920 lbs.
	8-inch		256 lbs.
	6-inch		100 lbs.
	4.7 A.A.		50 lbs.
	Multiple pom-pom		2 lbs.



K 140



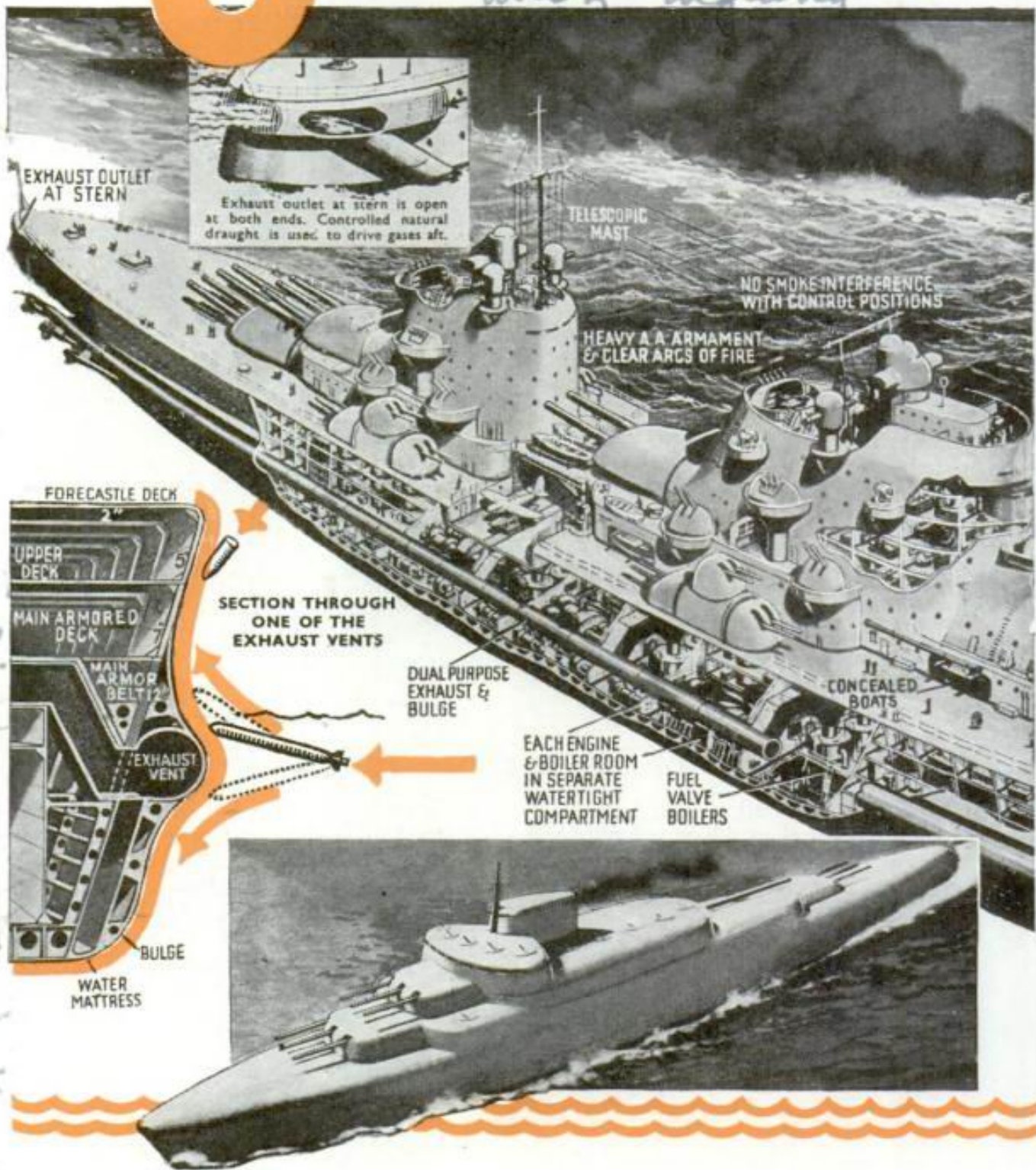
All drawn to the same scale, these are the notable types of fighting tanks of the European armies. British tanks generally prefer speed to thick armor, French the reverse. All have revolving gun turrets, and in each case the driver is between the wheels. Numbers under tanks indicate width of trench the machine can span; down the left side of the drawing are the angles of slope the tank can climb, at right are the heights of abrupt steps it can surmount



Largest aircraft in the British coastal command is the "Sunderland" flying boat. With a 2,800-mile range, these reconnaissance bombers "cover" the North Sea and northeastern Atlantic. Big enough to pick up the entire crew of a merchant vessel, they have participated in a number of rescues. The four engines develop 4,040 maximum horsepower and cruise at 178 miles an hour, with 22,000-foot ceiling. The ship carries seven machine guns, is manned by a crew of eight

K622 *Admiral Press Ltd* *93, Engineer London* *W22 Island*

BATTLESHIP

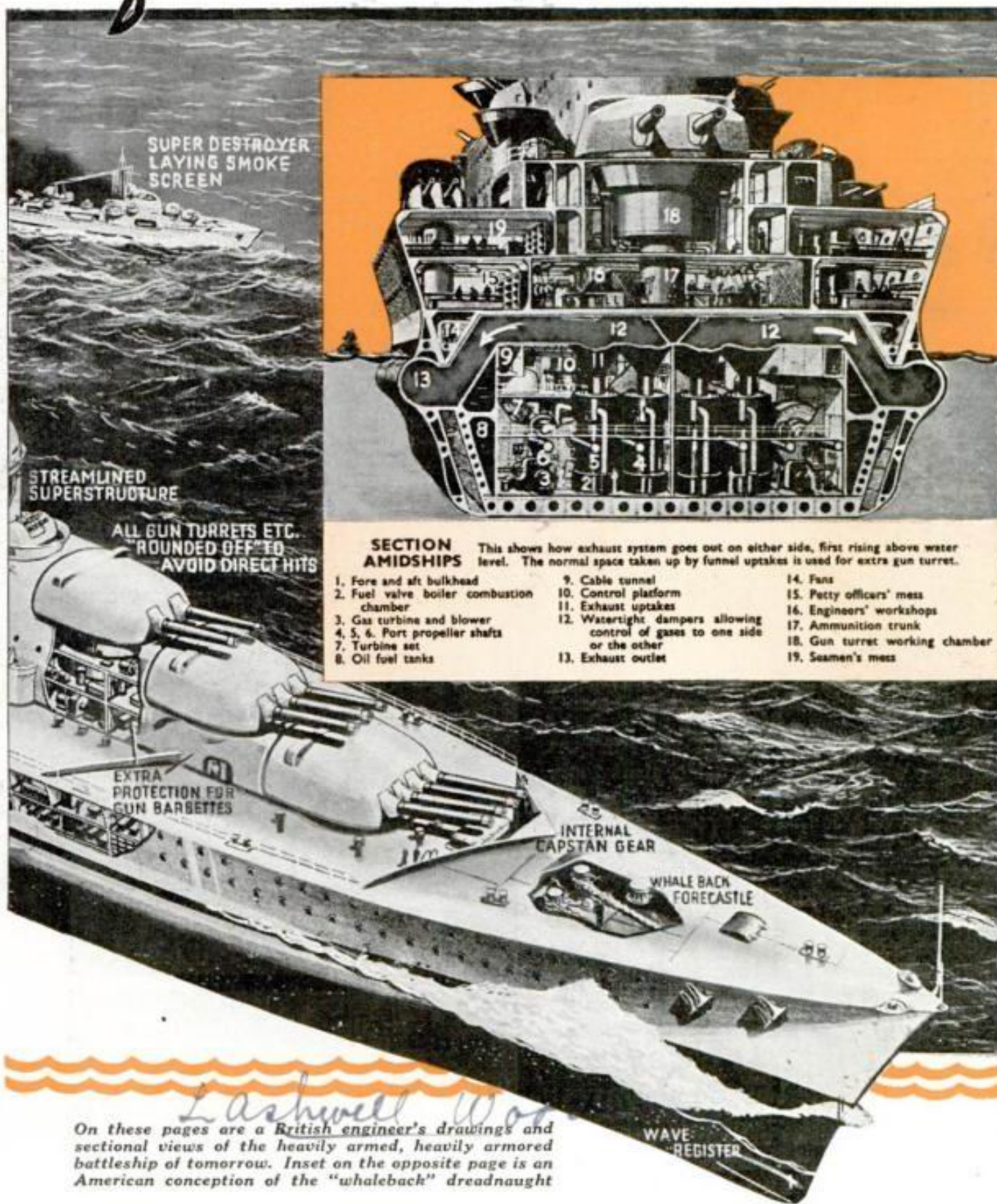


RADICAL changes in dreadnaught design are coming out of the war tests between battleship and bomber, chief among them the streamlining of decks and turrets, not for aerodynamic reasons but to fend off aerial bombs, and the multiplication of anti-aircraft batteries. Otto Kuhler, American designer, suggests the whale-

back battleship at the bottom of this page, its foredeck roofed with heavy armor plate, quantities of anti-aircraft guns over the enclosed bridge and streamlined aft turret, below which is a hangar housing bombers, fighters and reconnaissance planes launched by catapult. The larger drawing is that of an English designer, showing

K.622.

of the FUTURE



Lashwell
On these pages are a British engineer's drawings and sectional views of the heavily armed, heavily armored battleship of tomorrow. Inset on the opposite page is an American conception of the "whaleback" dreadnaught

similar arched superstructure designed to let bombs and shells ricochet off with minimum damage. This battleship would have exhaust outlets at the stern, displacing the conventional funnel, and its 70,000 tons

would call for turbines of 252,000 horsepower driving six propellers. Armament includes eighteen 14-inch guns, twenty-four 5.25-inch guns, sixteen 4.7-inch anti-aircraft guns and seven multiple pompoms.

Popular Mechanics Magazine

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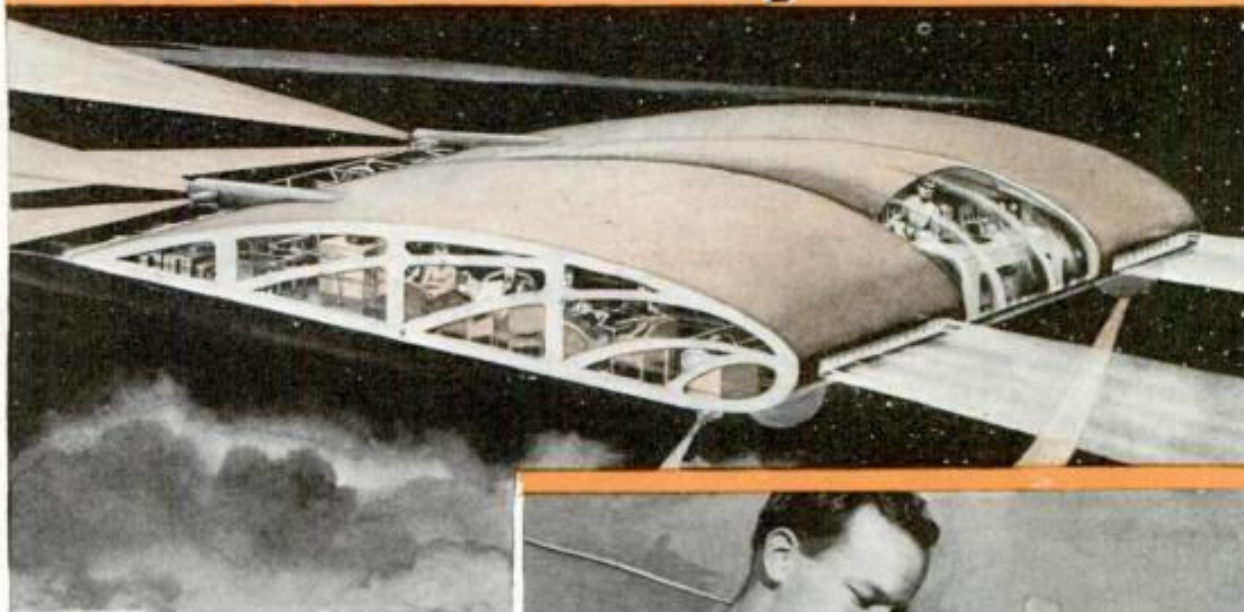
WRITTEN SO YOU CAN UNDERSTAND IT

Vol. 75

JANUARY, 1941

No. 1

The MIRACLE of U-235



By Dr. R. M. Langer

Editor's Note—One of the country's eminent physicists in this article paints a picture of the world as he visualizes it when U-235, a possible new source of power, emerges from the laboratory. Dr. Langer, now at the California Institute of Technology, has been doing uranium atom research and has been connected with leading laboratories in this country and abroad

Pasadena Calif
SEVERAL months ago you read in Popular Mechanics that the secret of atomic power is close to solution and that possibly within a decade civilization will be using the tremendous amounts of energy contained in U-235, an isotope of uranium.

Since then, additional research has opened up greater possibilities than ever. At first we thought that a heavy power plant weighing tons would be required to extract the power; now it appears that a pound or even a single ounce of



Top, author's idea of U-235 plane, a flying wing with propelling jets at rear and lifting jets underneath. Cross-section treatment gives view of interior. Bottom, giant electron microscope developed as result of atomic studies

JANUARY, 1941

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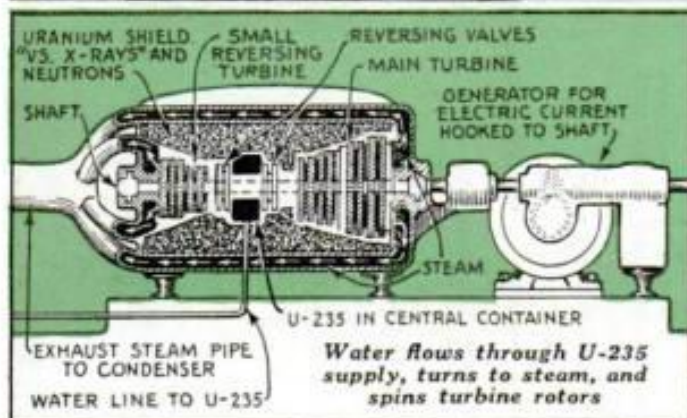
closed within a streamline shell. The Santa Fe railroad soon will have in service some passenger coaches built according to this principle. They are called pendulum cars by Hill, Van Horn, and Lindval, the three young men mainly responsible for this important new invention.

Because of the stability and smoothness of our future cars, all sorts of work can be carried on in the interior compartments. The automatic character of control

should make it possible to drive the car from almost any position, simply holding the remote-control panel in your hand. On a main highway cars can be kept in lanes by buried pilot cables similar to the electrical devices used to guide ships into harbors.

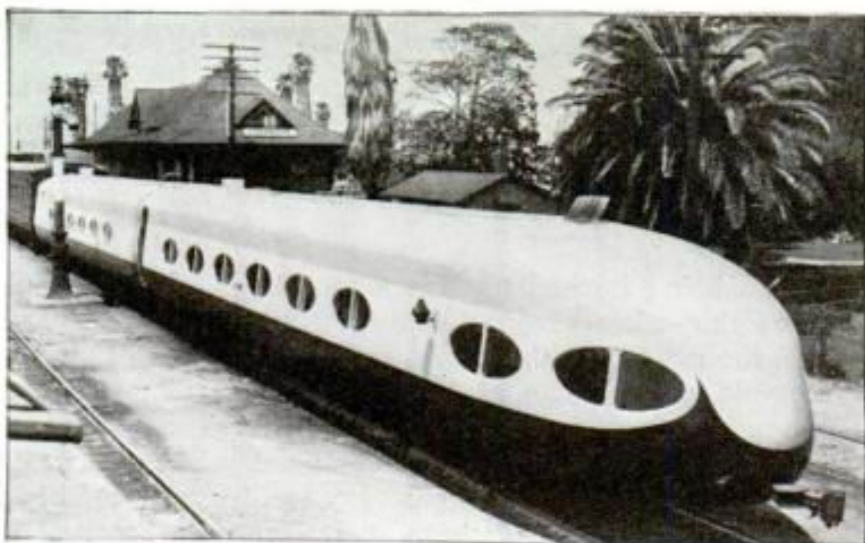
The most important unit of the new era is the motor that will supply energy for all rotating shafts. It is already complete in principle although many improvements probably will be made. This "butterfly" motor, or U-235 engine, is capable of any speed or torque that is likely to be demanded of it. Its other qualities are ease of manufacture, simplicity of operation and control, versatility of performance, and portability.

Postponing explanations for awhile, it is pointed out that water passed over U-235

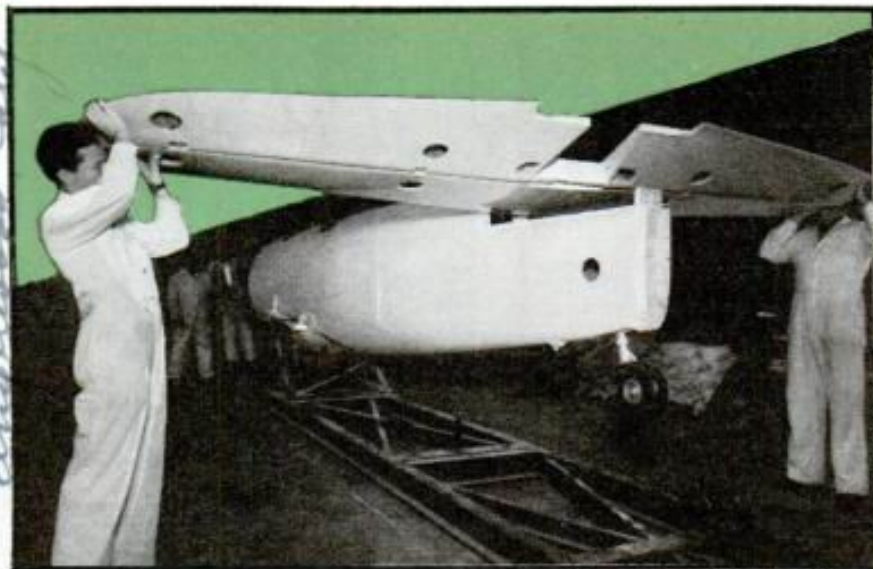


your choice between yesterday and tomorrow, because a speed of 2,000 miles per hour is about twice as fast as the rotation of the earth.

The automobile, like the airplane, will be of plastic material and built like an insect, with the skeleton outside. This monocoque construction provides lightness and strength and has a functional architectural beauty. Transparent portions can be made integral parts of the surface so that special window frames are avoided. The whole is molded in one process and the assembly job becomes as easy as cooking a waffle. The body is supported at the top so that when the car goes into a turn the bottom swings out to provide an automatic bank. The chassis has overhead frames from which the body is slung. The whole structure is, however, en-



Top, apparatus for separating elements into their isotopes. This can be used to produce U-235, but the method is too slow for practical production purposes. Below, "butterfly" engine that would use U-235 and water. Bottom, pendulum coach, already built, employs overhead suspension



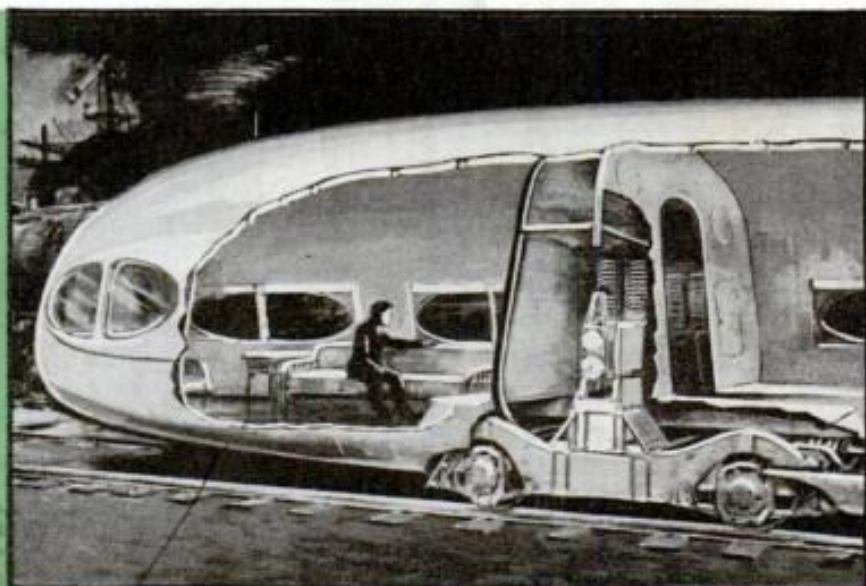
Above, assembling plastic plane. Bottom of page, left, examining spring suspension in pendulum railway car shown in cutaway sketch at right. Auto of uranium age will be constructed similarly, the author believes



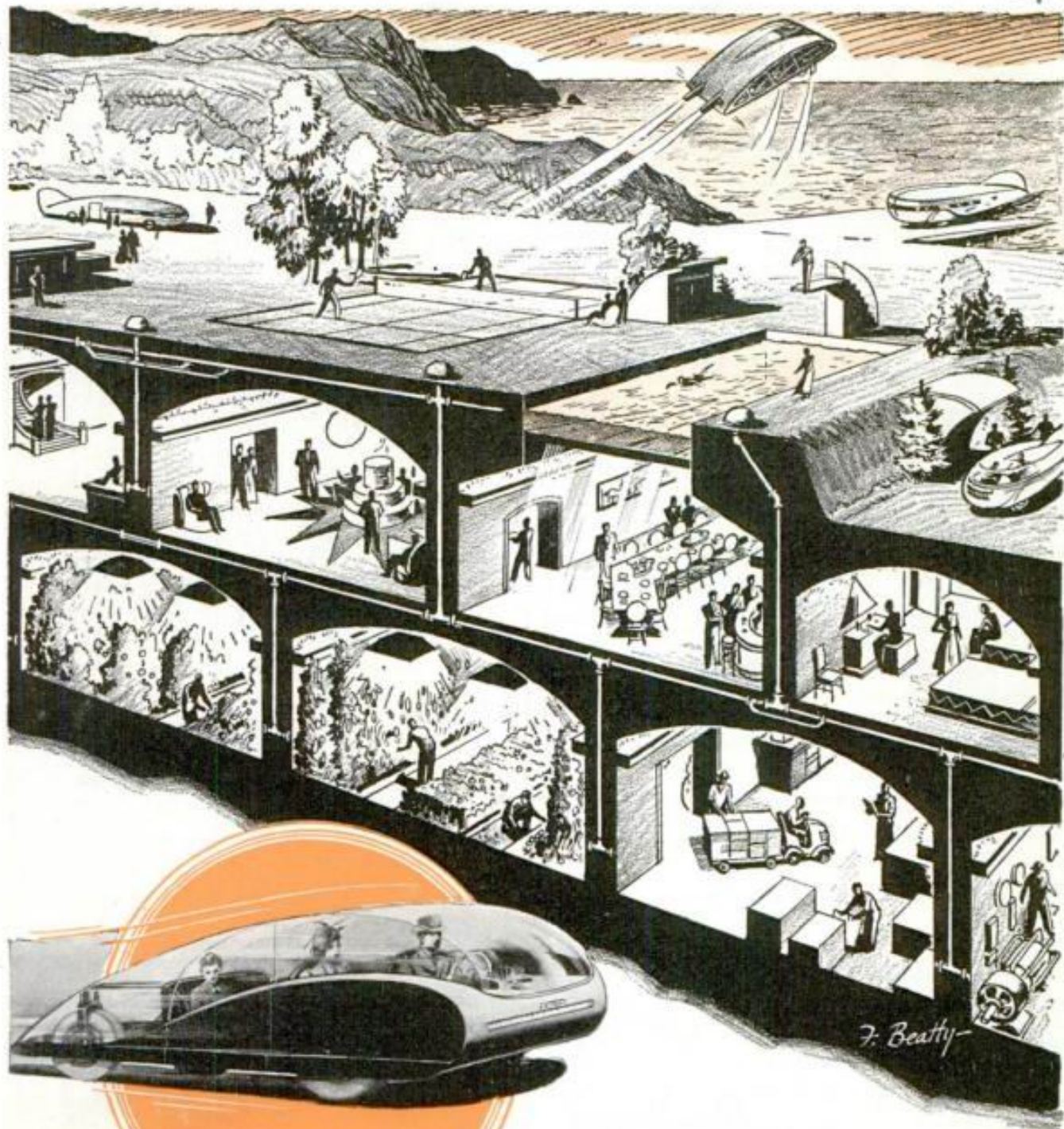
U-235 can be made to deliver energy. A power plant the size of a typewriter will be available. Its heart will be a one-pound package of uranium that contains the same amount of power that we extract from 250,000 gallons of gasoline. With such a power pack in a car you could drive 5,000,000 miles without refueling. Obviously, at \$1,000 a pound, U-235 will be cheap.

But more miles per dollar is only one minor advantage foreseen for the uranium age. We can look forward to universal comfort, practically free transportation, and unlimited supplies of materials. Power will be cheap in every home and factory, without distribution lines, and electricity will cost less than one-tenth of a cent per kilowatt-hour.

It is not too early today to consider the changes that this power source suggests. Jet propulsion will free the airplane from earth. For both local low-altitude trips and long-range flights at high altitudes we will probably always use the simple airfoil or flying-wing design. We will use the principle of rocket power but there will be no need to employ the bullet shape of present rockets. We will fly several thousand miles per hour at several hundred thousand feet above the surface and will have to slow down in descending to the surface



K 999



Above, author's ideas of what life may be like in uranium age. Note that most activities are located underground—even farming. Only transportation and recreation are above the surface. Left, Dr. Langer's conception of the U-235 automobile

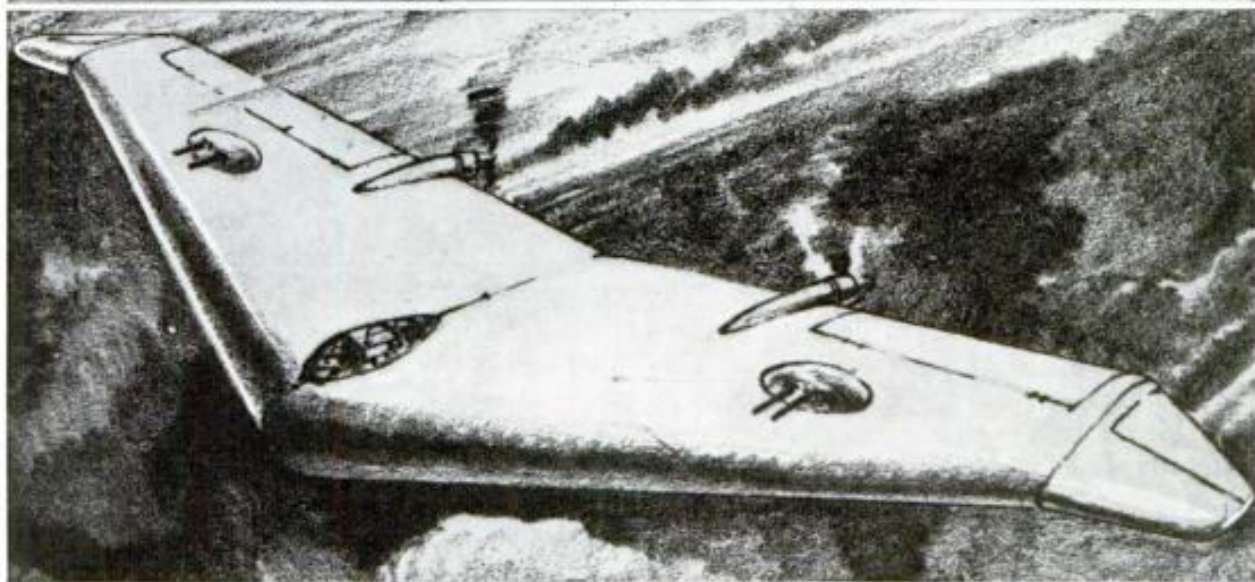
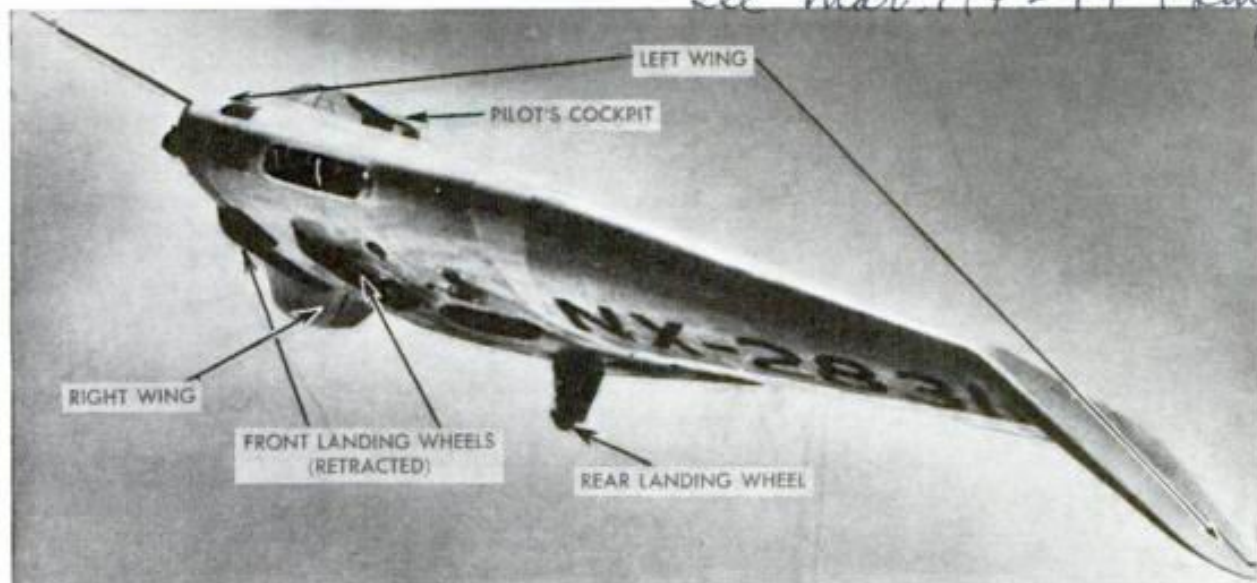
to avoid being burned up like a meteor.

The flying-wing driver will have a gyroscope, the main propulsion jets, and a few directable control jets at his command. Compressed air or steam for the jets might do for landing or leaving the ground but for greater efficiency we might very well use steel vapor for propulsion at higher altitudes. Vapor from boiling steel would have powerful thrust and would condense as fine harmless dust.

The concept of neighborhood changes in a world where no two points are more than seven flying hours apart. It is all one big community and there is no excuse for differences in material welfare. If you feel like cold weather, some afternoon, you can go and get it. If you want a tropical swim the day before Christmas, that is easily arranged, and you can be back in time for Santa Claus. You can choose night or day according to your mood and you may have

Two-Motored "Flying Wing" Has No Fuselage

21179
all mar 1942 14 (Long)



Details of batlike plane remain a secret, but photo and sketch reveal some of its striking features

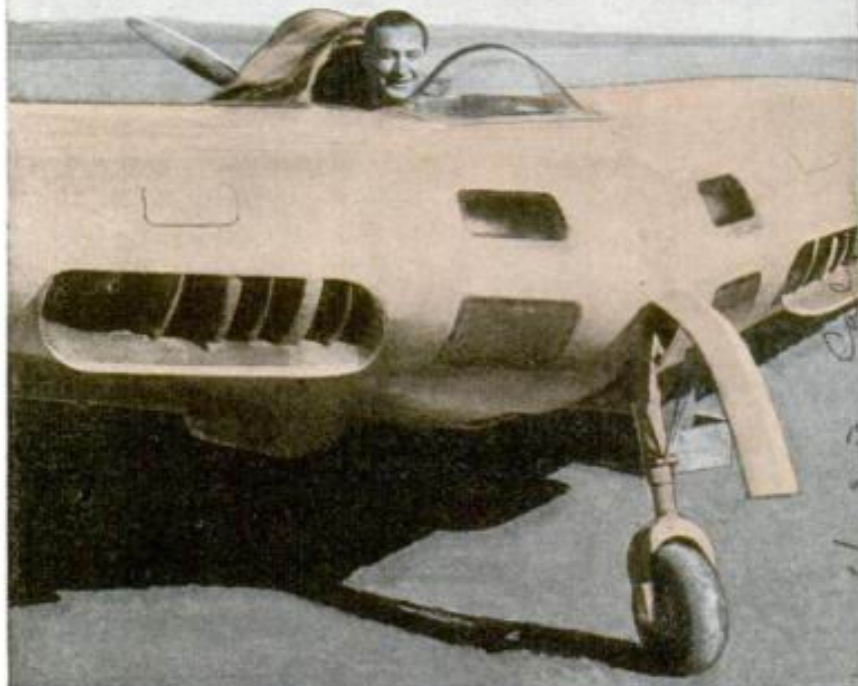
Consisting of a thick triangular wing, with no tail and no fuselage, a revolutionary airplane has been completed and test-flown in secrecy by Northrop Aircraft, Inc., under the watchful eyes of the United States Army Air Forces. Lack of maneuverability, the bugbear of previous "flying wings," is overcome with a sharp downward tilt of the wing tips that apparently include rudders and ailerons. What seem to be elevators nestle in the trailing edge of the massive wing. It also encloses two flat liquid-cooled engines, each driving a four-bladed pusher-type propeller. The cockpit is located on top near the foremost point. For war purposes guns will probably point from blisterlike turrets on the wing's upper surface. Because of the increased "lift" gained by using nearly every

square inch of its surface, and the virtual elimination of drag, the plane is expected to fly faster than many pursuit ships.

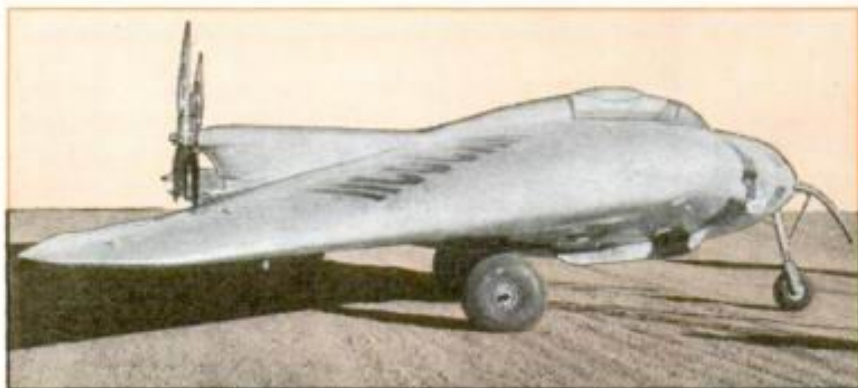
Two-Ray Radio Tours Streets To Regulate Transit Lines

Cars equipped with frequency-modulation radio will play an important part in keeping the Cleveland Railway Company's transit system running efficiently. Ten such units, each carrying a 25-watt two-way radio supplied by General Electric, are used to patrol the city's lines, reporting on traffic conditions to headquarters where there is a 250-watt transmitting station. Whenever fires or other troubles impede traffic, the radio cars will render valuable assistance in rerouting the transit vehicles.

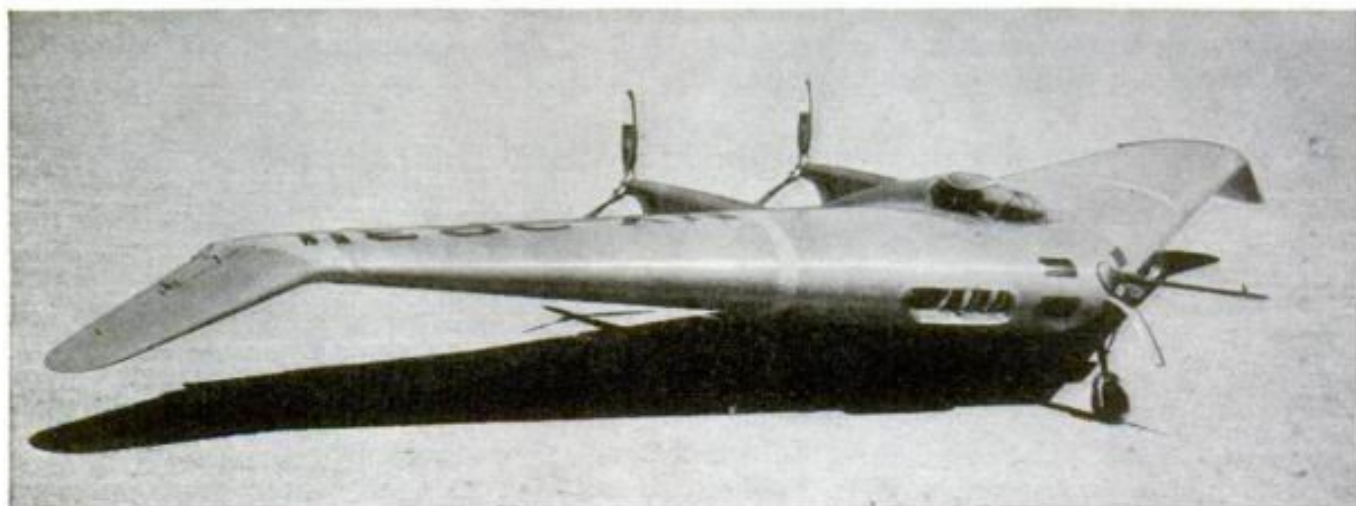
21369 Capt. Thomas G. Stinson Jr.
3842 Francisco Ave
FLYING WINGS ARE COMING
(See Jan. 1942 25) Los Angeles



Above, a closeup of center section of the flying-wing plane with Northrop in cockpit. Openings admit air to carburetor and to cool engines



Side view, above, shows tips rebuilt horizontally into the wing; notice extreme thickness of the center section. Spear projecting from apex of wing in the photograph below is the air-speed indicator tube



THE old prospector rubbed his beard and squinted in amazement.

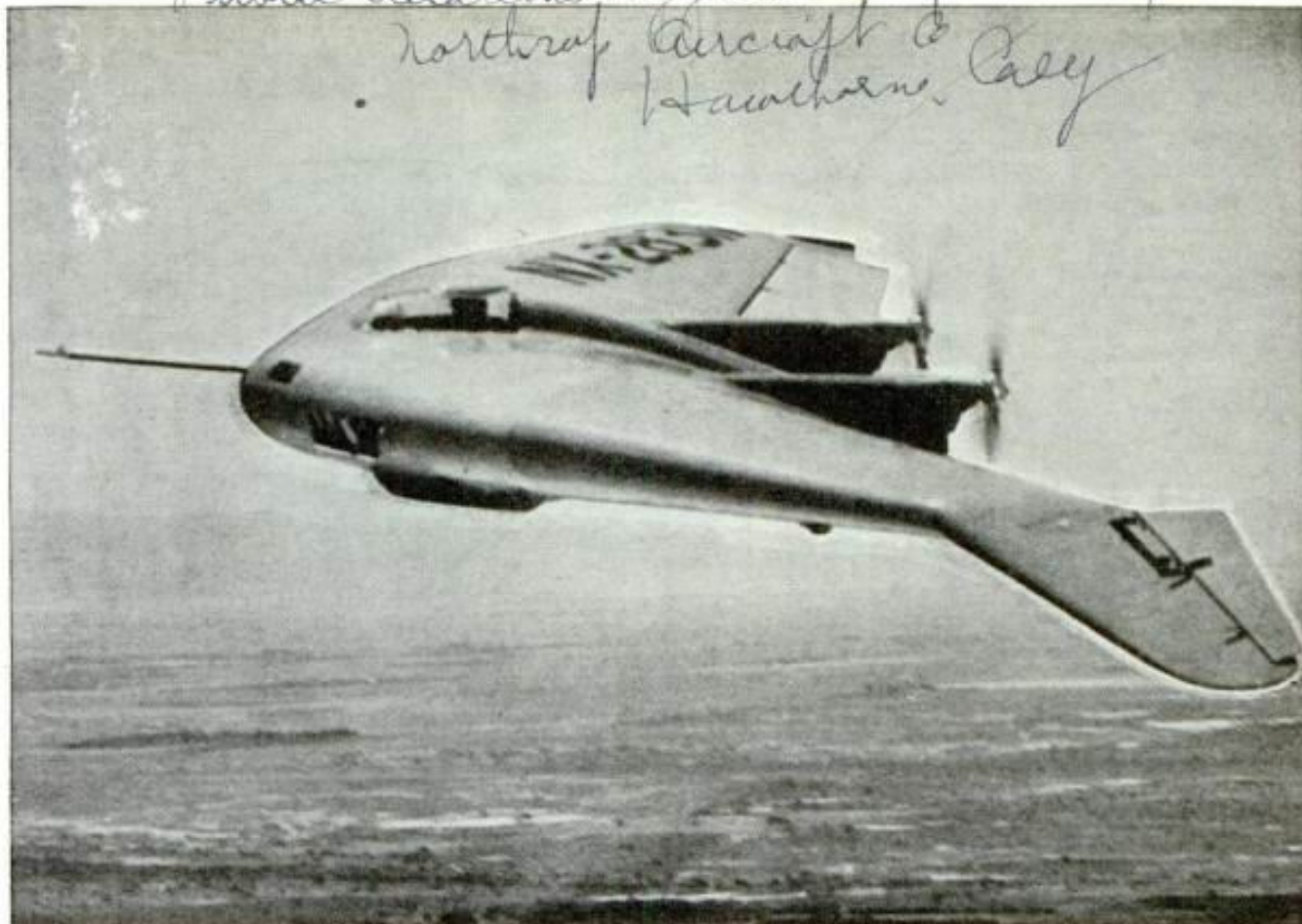
"It's the heat," he muttered. "There just ain't any airplane like that."

Swooping over the California desert was something that looked to him like a monstrous pterodactyl. It had to be an airplane, he finally decided, because he could hear the motors. But it was the queerest the desert had ever seen. It didn't have any tail.

What the prospector had stumbled across was a secret test flight of a new plane that no one except a few Army officers and Northrop Aircraft officials knew about. It was a flying wing that some engineers expect will revolutionize aircraft design. Some predict today's conventional airplane will become as extinct as the pterodactyl that the new flying wing resembles. Already Northrop is getting into volume production on the type.

Designers have been trying to perfect a practical flying wing for dec-

Ref: Lyle Manton
Public Relations Office
Northrup Aircraft Co.
Hawthorne, Calif. 21369



ades because such a craft is about one third more efficient than an ordinary airplane. The conventional tail and fuselage are hindrances to efficient flight, but the tail group has been necessary for control, and the fuselage necessary to hold the tail behind the wing. Both elements form a drag that holds the wing back from the speed it could attain by itself.

A number of flying wings have been built, one as early as 1914, but all were hard to control. Even a flying wing needs control surfaces and the only places to put them are at the wing tips. This creates a short coupling that results in bad spinning characteristics. Such flying wings are perfectly stable in smooth air but

(Continued to page 190)

In flight, the great sweepback of the wing is seen. Notice control surfaces in wing tip and the clean lines of this craft when its tricycle landing gear is retracted. Below, its pusher engines hidden from this angle, it is shown in contrast with a conventional monoplane



More Power for America

POPULAR MECHANICS MAGAZINE

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SEE PAGE 14

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FLYING CARRIER

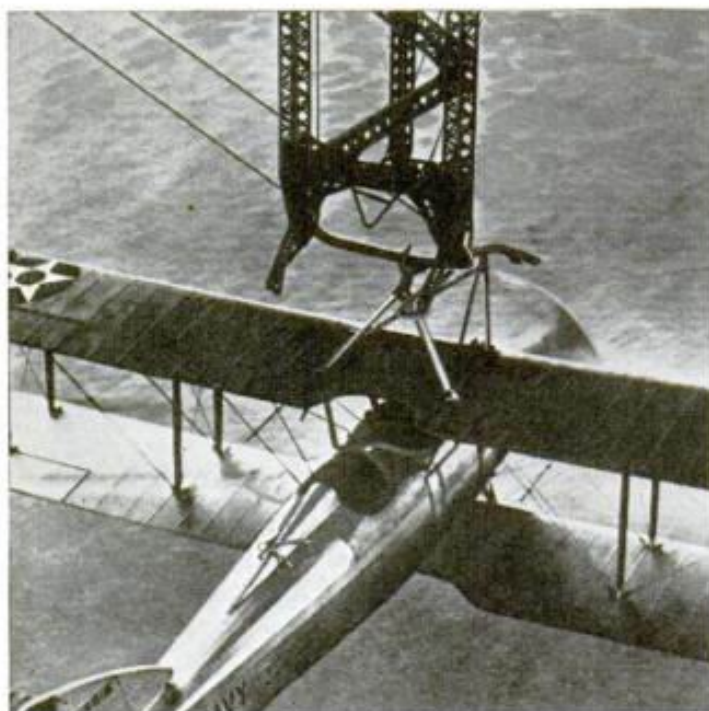


Cutaway view of flying carrier for bombing planes

Acme

Courtesy Goodyear Co.

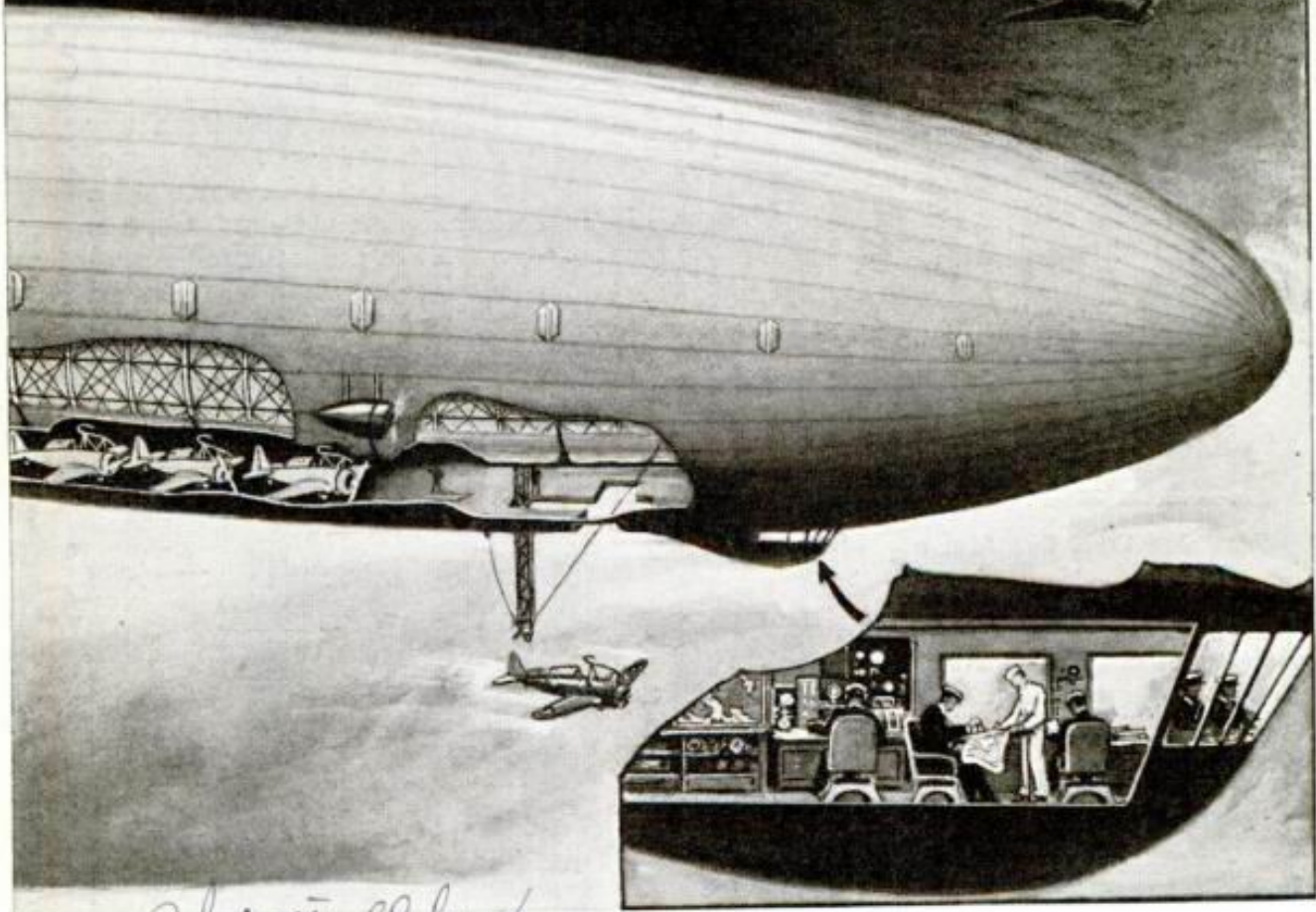
Closeup of hook-on arrangement, which permits airship to launch and pick up planes, employed in extensive tests



RIGID airships, each carrying ten attack bombing planes and capable of ranging thousands of miles from their bases, might be employed effectively by the United States Navy, according to lighter-than-aircraft experts. One type, designed by the Goodyear Tire and Rubber Company, pioneer builders, would have a capacity of 10,000,000 cubic feet of helium, the nonexplosive and nonburning gas of which America has the only large source of supply. It would have a top speed of 84 nautical miles per hour and a cruising speed of 50, more than twice the speed of surface aircraft carriers. This flying carrier would operate in conjunction with other units of the navy, including aircraft carriers. Immune, of course, to submarine attack, the airship would be expected to operate be-

m135

for WARPLANES

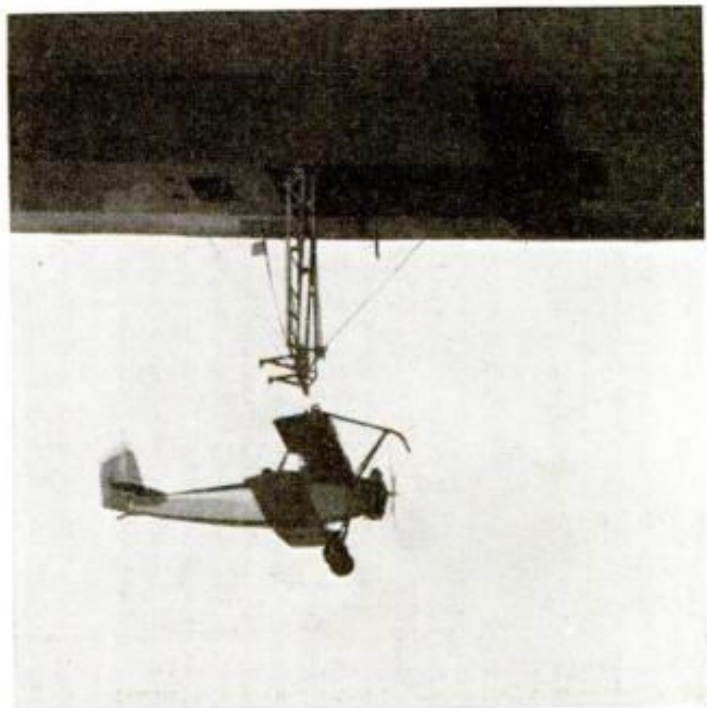


Akron class

yond the range of land-based enemy planes and at altitudes above the effective gun range of surface vessels. In case of attack, it would be able to take refuge in the clouds while its own planes streamed out to meet the enemy. It is known that planes can be launched and retrieved by airships because more than 3,000 such operations were made with the airships Akron and Macon a few years back. Launching is accomplished by lowering the plane, attached to a sort of trapeze bar by means of a hook, through a trapdoor. Then, with the plane's motor or motors roaring the pilot releases the hook and the plane drops away. Upon its return to the "mother ship," the plane attaches itself to the trapeze bar by means of the hook as the two fly at virtually equal speeds. Then the plane is drawn into the airship.

Control cabin as visualized by artist; arrow shows location

Plane just dropping away from the "trapeze bar." Above is trapdoor through which planes are lowered for launching





Planes of Tomorrow

By Glenn L. Martin

POPULAR MECHANICS MAGAZINE

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SEE PAGE 1



BUY UNITED STATES
WAR SAVINGS
BONDS AND STAMPS

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Vol. 78

SEPTEMBER, 1942

No. 3

PLANES *of* TOMORROW



M 628

This is the plane of tomorrow, a 125-ton leviathan designed by Martin

By Glenn L. Martin

President, The Glenn L. Martin Company.

Baltimore, Md.

WHAT'S ahead for aircraft in peace and war?

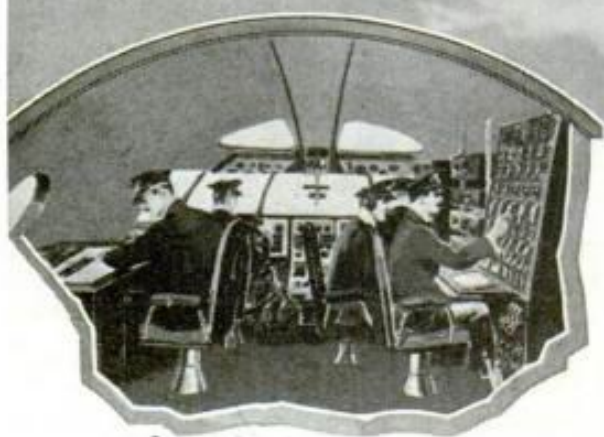
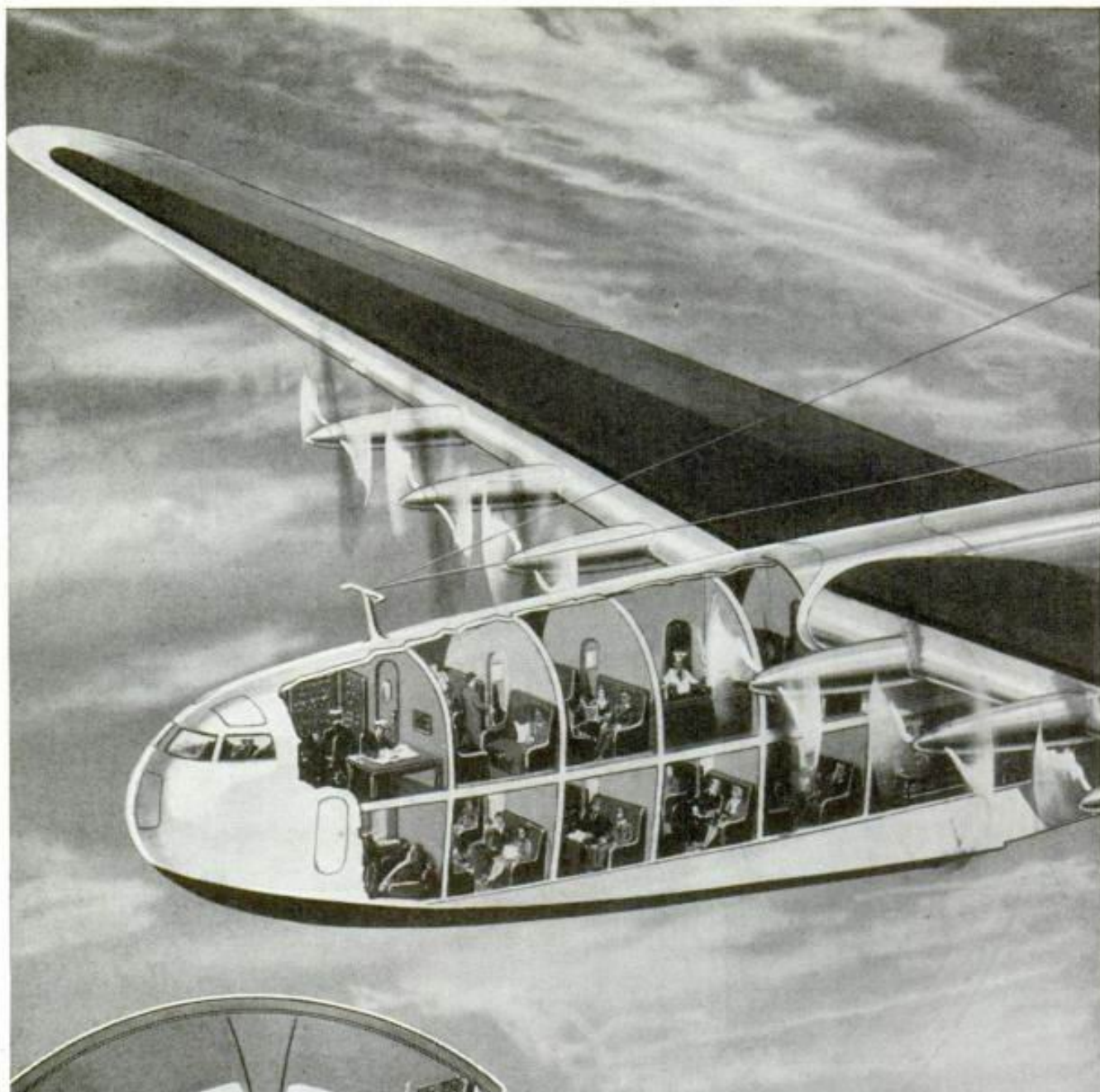
I am not a military expert. But I have spent a lifetime in the design and production of military aircraft. In 1913 it was my privilege to help conduct the Army's first bombardment experiments at San Diego. So fascinated was I with the airplane's demolition possibilities that I made this statement, culled from newspapers of August 7,

1914, which were headlining the beginning of World War I:

"The aeroplane will practically decide the war in Europe. Veritable flying death will smash armies, wreck mammoth battleships and bring the whole world to a vivid realization of the awful possibilities of a few men and a few swift aerial demons. For the old-time war tactics are no more. The generals who realize this quickest and

SEPTEMBER, 1942

1



Drawings and photos from Glenn L. Martin Co.

Across the pages is a sectional drawing of the six-engine transoceanic hotel, which would fly from New York to London in less time than you ride a train from Chicago to New York. Left, the huge flight deck

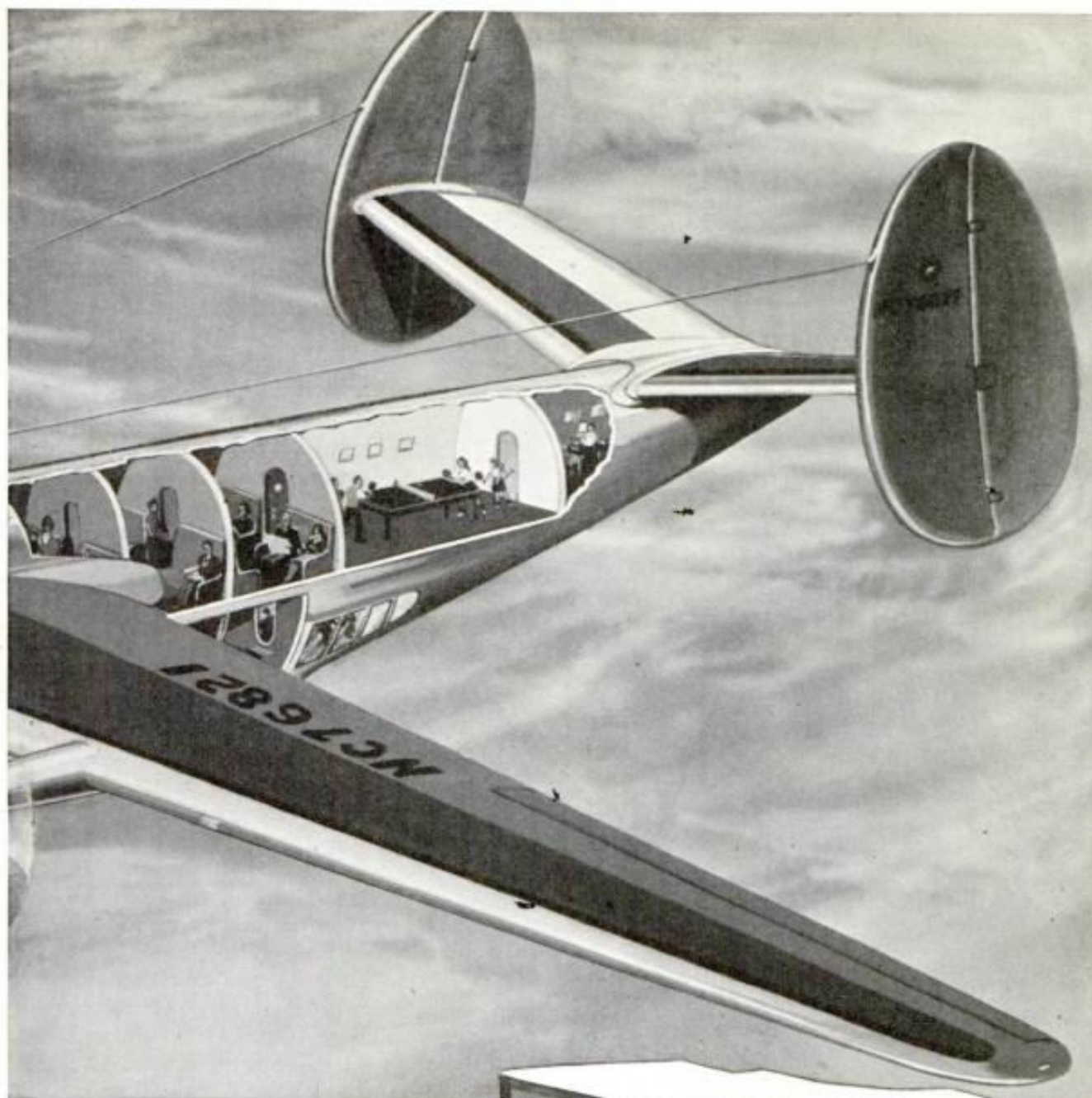
fight first with the flying death, will win."

I was one war too early on that one. But today we find air forces the most powerful influence in victories; lack of them, the outstanding cause of defeats. No armed force can be successful in any major project without air supremacy in its theater of war.

Few stop to consider the versatility of

aircraft in this war. In addition to its more spectacular functions of bombardment and defense, the airplane is maid-of-all-work for the armed services. It performs long-range reconnaissance, patrol and scouting work for Army and Navy. It transports troops and heavy loads of supplies at high speed. It is a moving and elusive machine-gun nest. In some situations it is a basic supply source for soldiery.

Too few understand the power of the airplane—rather, the fleet of airplanes—as long range artillery. Let me excite your imagination with a hypothetical mission.



Word arrives at a battleship station that a hostile force has been sighted 1,000 miles away. The battleship is stocked with supplies and ready for battle. In 38 hours, if the target has not moved too far, the first salvo of nine tons of explosives will be fired at the target.

Now a fleet of 150 bombers, costing about the same as a battleship, gets word of the force 1,000 miles away. In six and a half hours these planes discharge 750 tons of explosives on the target; in 38 hours, 2,250 tons of bombs will have fallen on the objective. Even a continuous cannonade from the battleship could not ap-



Observation rooms will offer a spectacular view during the ocean crossing. Except for swimming pool and open-air deck the plane will compete with the luxuries of a surface liner

SAUNDERS-ROE 45 COMPARED WITH

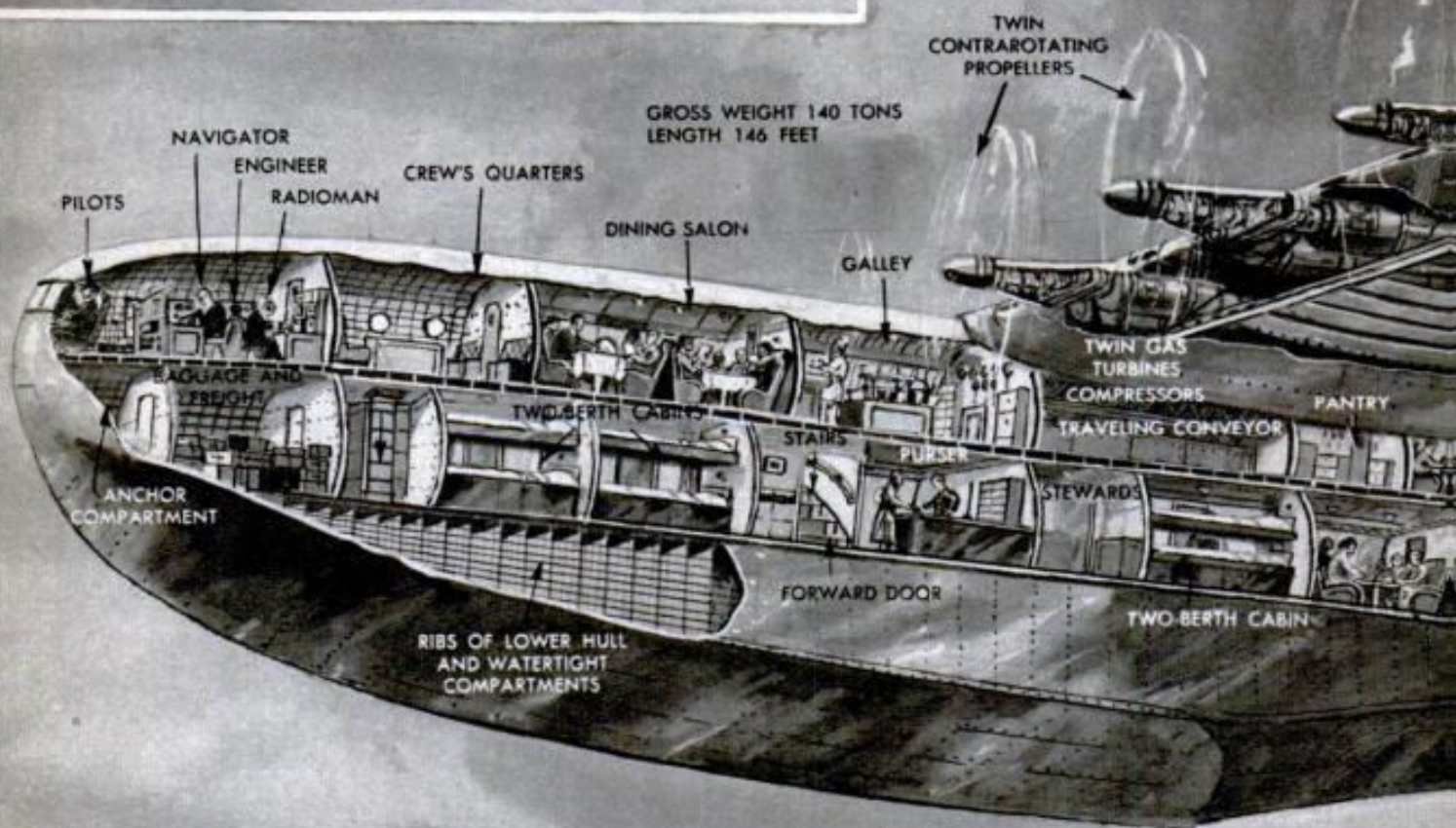
OTHER LARGE FLYING BOATS

MARTIN MARS

S.R. 45

HUGHES HERCULES

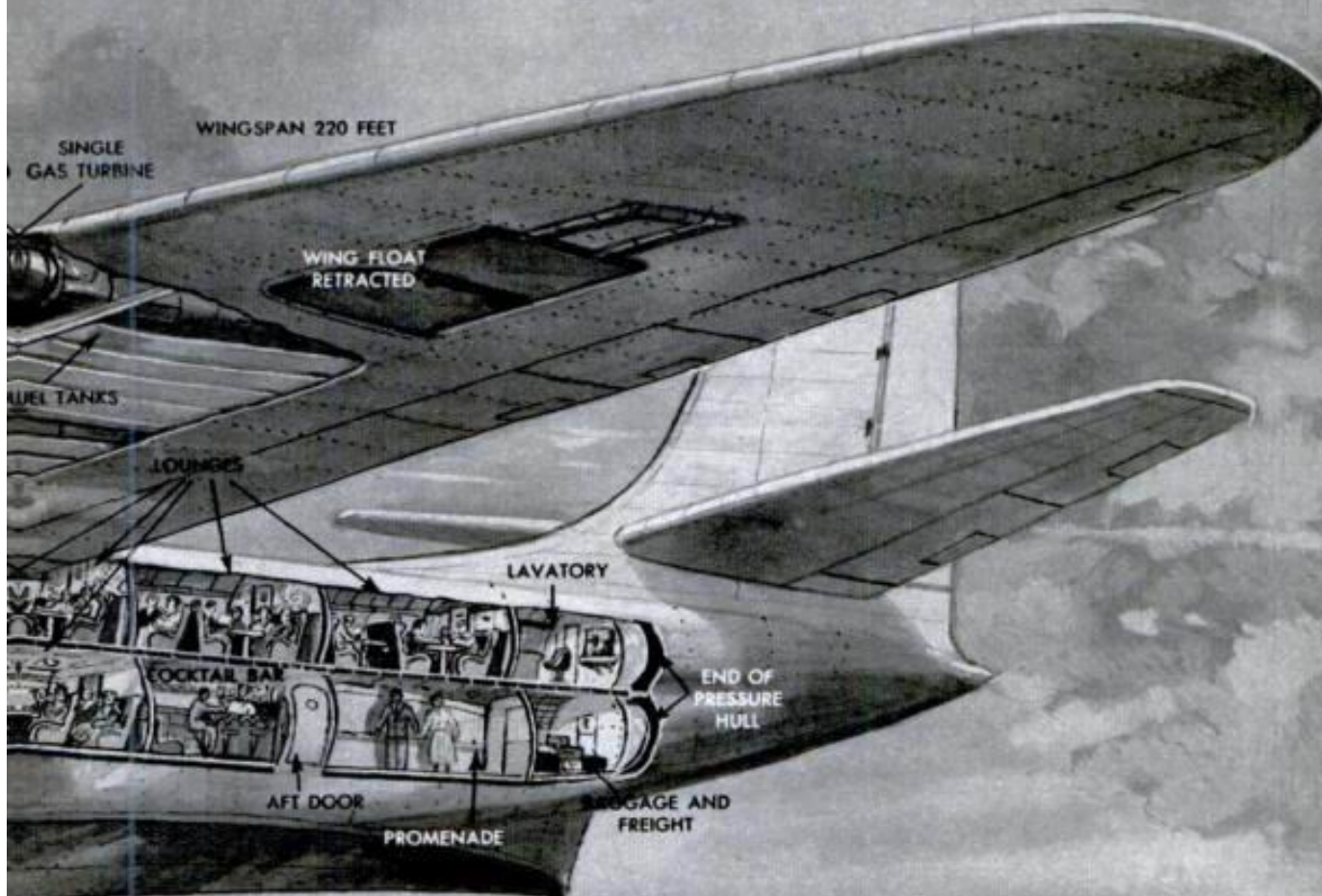
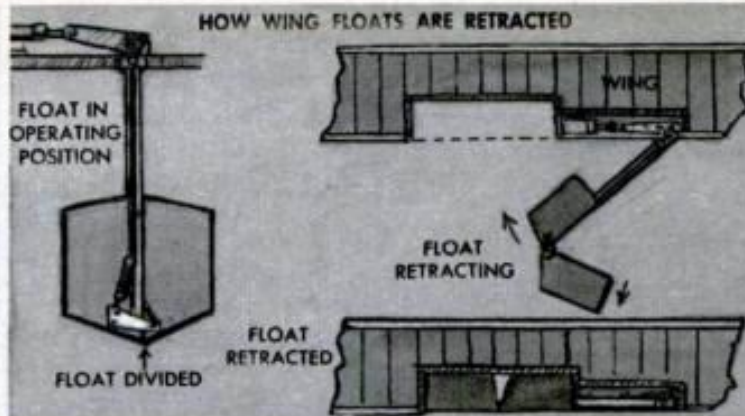
BRITAIN'S



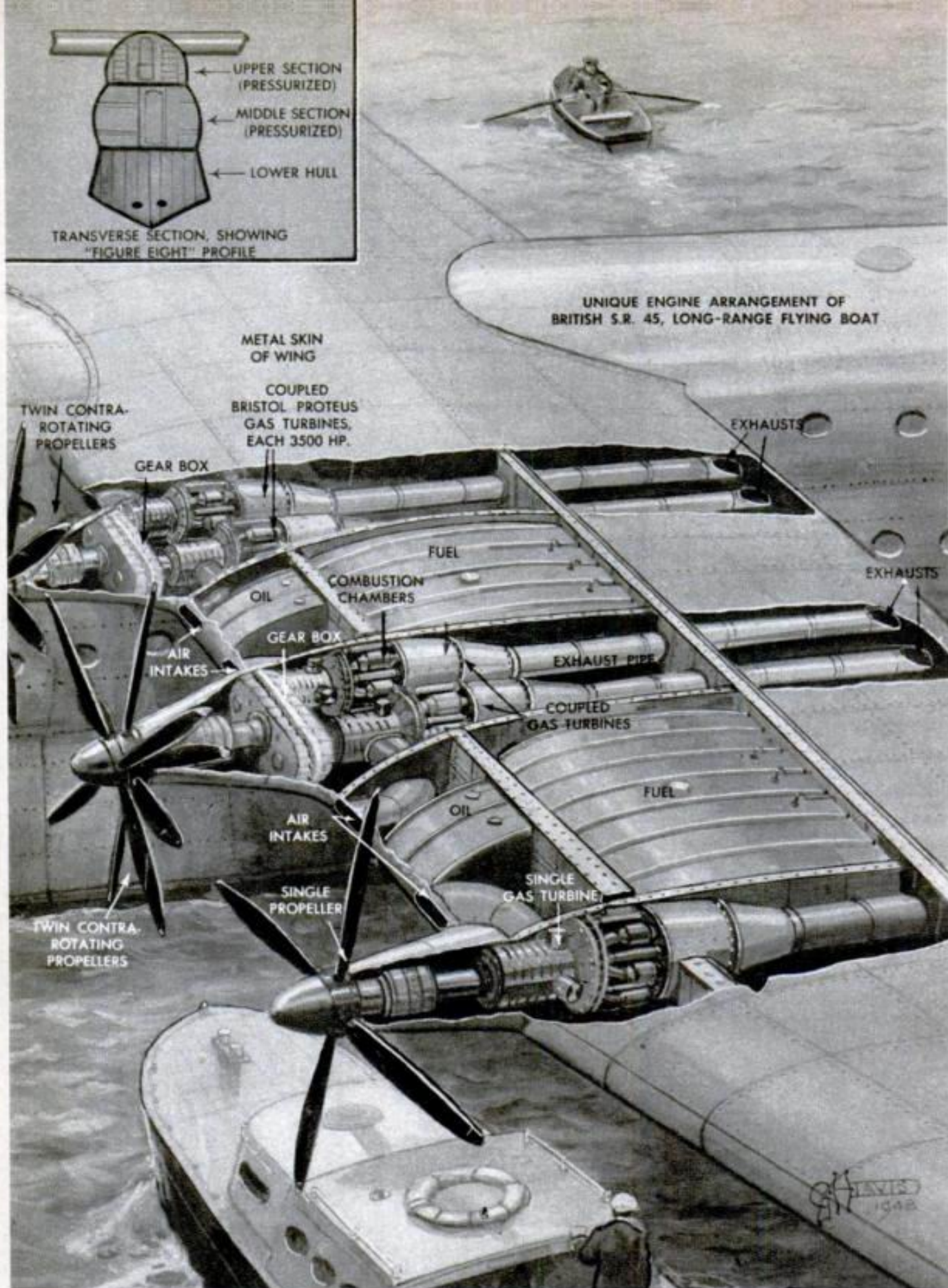
G. H. TAVIS
1948



BIGGEST Flying Boat



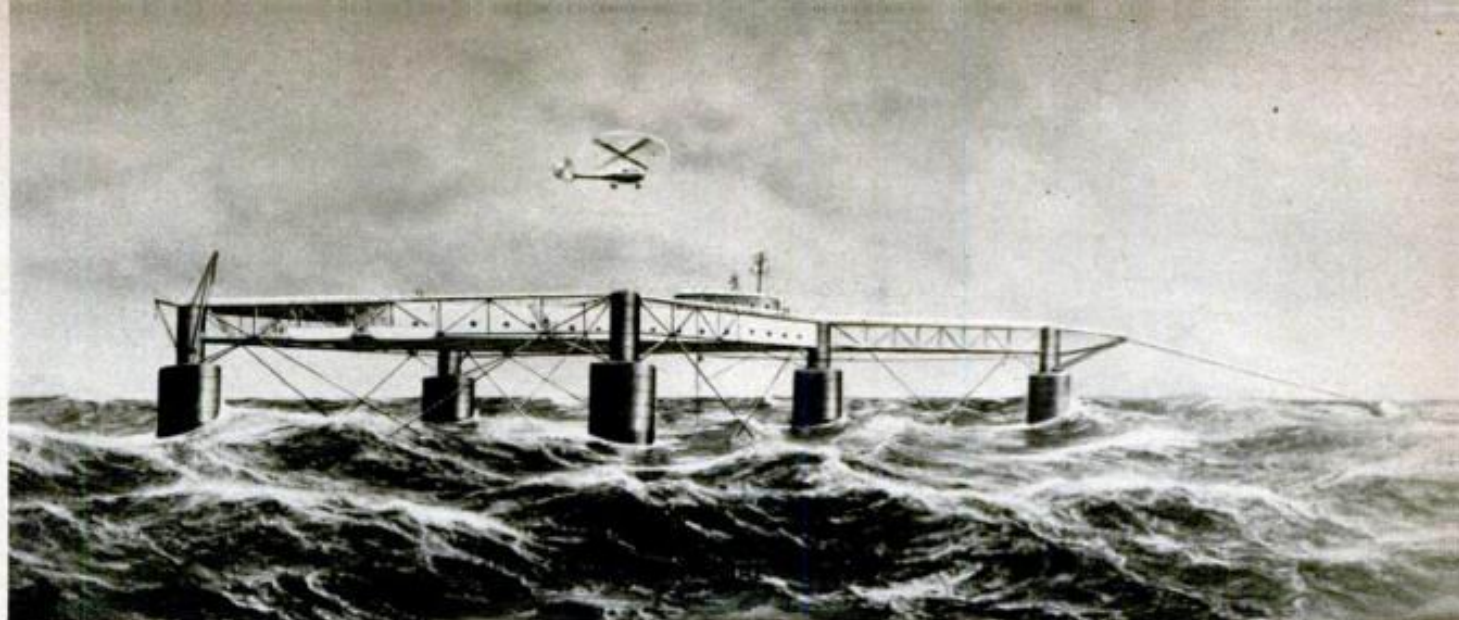
FLOATS that "break in two" and fold snugly up into the wings will be pioneered when the Saunders-Roe 45, Britain's largest flying boat, takes to the air next year. To streamline the 140-ton craft for 350-mile-an-hour flights, the two floats are divided into watertight halves. During retraction the halves gradually hinge apart until they assume a thinner, flat shape that can be drawn up flush into the underneath side of the wing. (See upper-right illustration.) Eight of the plane's 10 gas-turbine engines, each 3500 horsepower, will work in pairs to turn four sets of contrarotating propellers. A special clutch system will make it possible for defective engines to be uncoupled in flight, with the other of the pair continuing to drive the propellers. The two outboard engines will be conventional installations. Cruising altitude will be above 30,000 feet. Three of the giant air boats are being built



Using two-stage reduction gears, eight engines work in pairs to turn four sets of contrarotating propellers

at Cowes, England, and each is expected to carry upwards of 100 passengers on direct New York-London service. From tail to nose they measure 146 feet, with wings

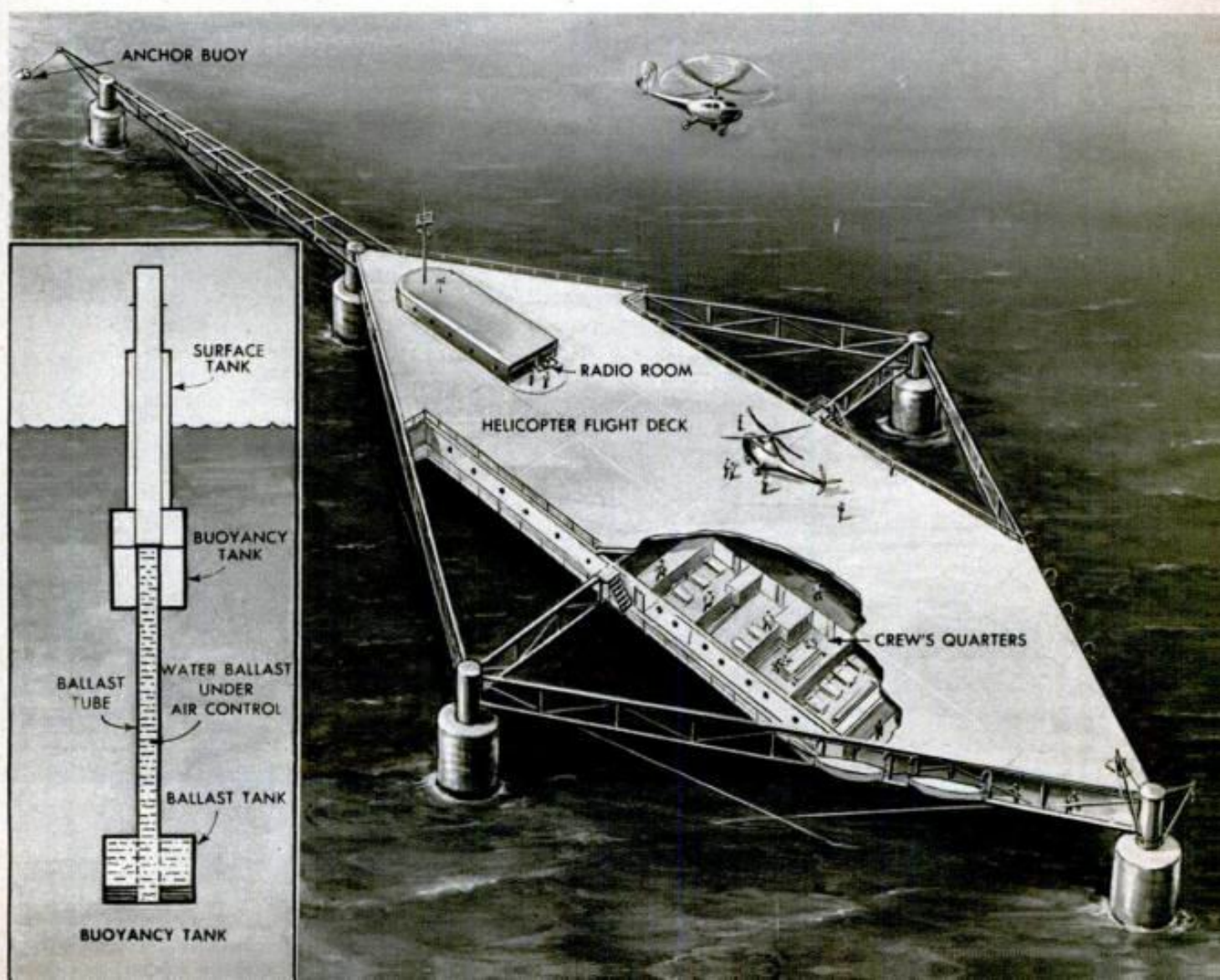
spanning 220 feet. The double-deck "figure eight" fuselage, which will be completely pressurized, is slightly more than 24 feet high at the center entrance.



Mid-Ocean Weatherdrome

WEATHER observations spanning the Atlantic may someday be made from floating weatherdromes anchored in the high seas. The Coast Guard has asked Congress for authority to proceed with plans for the floating islands. Invented by Edward R. Armstrong, the weatherdrome would have quarters for crew members who would report weather conditions to the mainland. The inventor's plans also call for a helicopter landing deck, although the Coast

Guard says that the weatherdrome will not be specifically designed as a landing field for planes. Weighing 2000 tons, the weatherdrome would have five supporting pylons extending 175 feet down into the water. Plans call for a girderlike extension 150 feet long to project out from the 300-foot main part of the station. This would give the unit a length of 450 feet, which is longer than any wave that might strike the structure. The station would be held in place by a dome-type anchor that would grip the ocean floor firmly through friction.



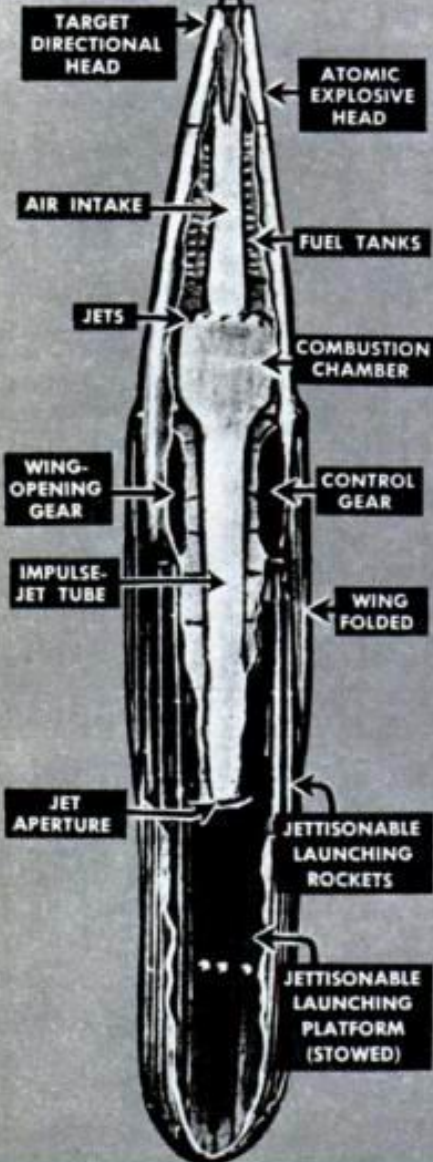
PREVIEW OF U-BOAT WAR?

THE LAUNCHING PLATFORM OPENS AT ONCE WHEN MISSILE REACHES THE SURFACE. THE MISSILE LAUNCHES ITSELF INTO THE AIR IN THE SAME SPLIT SECOND AND THE PLATFORM IS LEFT AFLOAT BUT SINKS LATER.

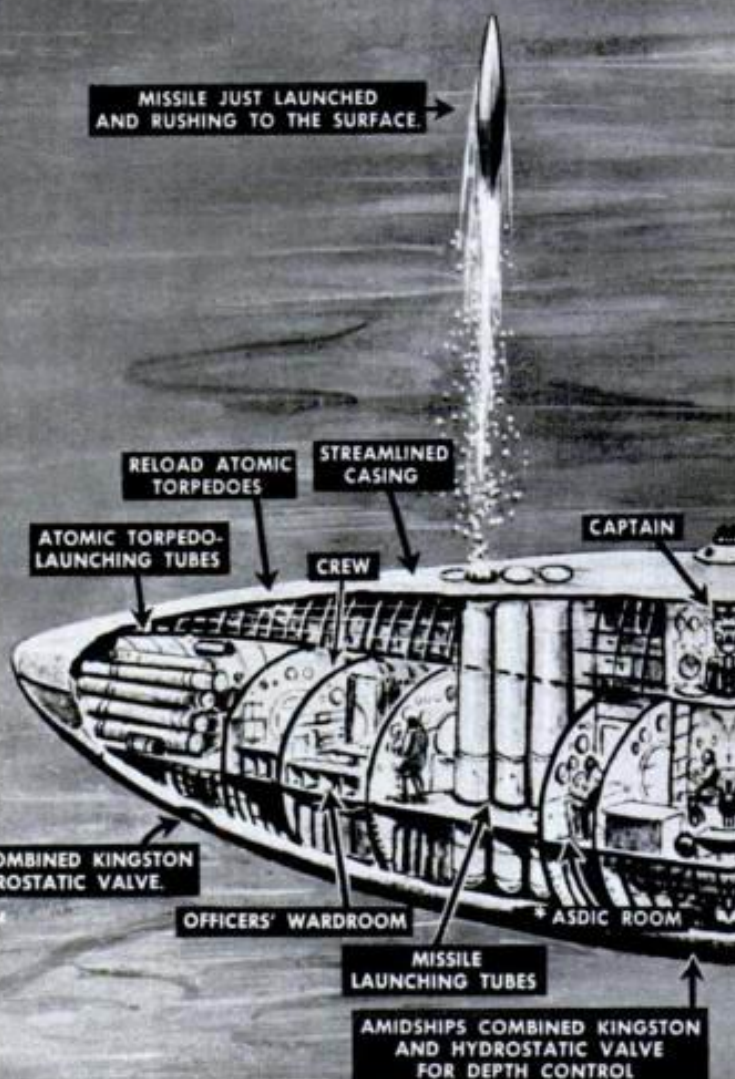


THE MISSILE, PROPELLED BY RAM-JET, COURSES TO ITS TARGET

A SUGGESTED TYPE OF MISSILE

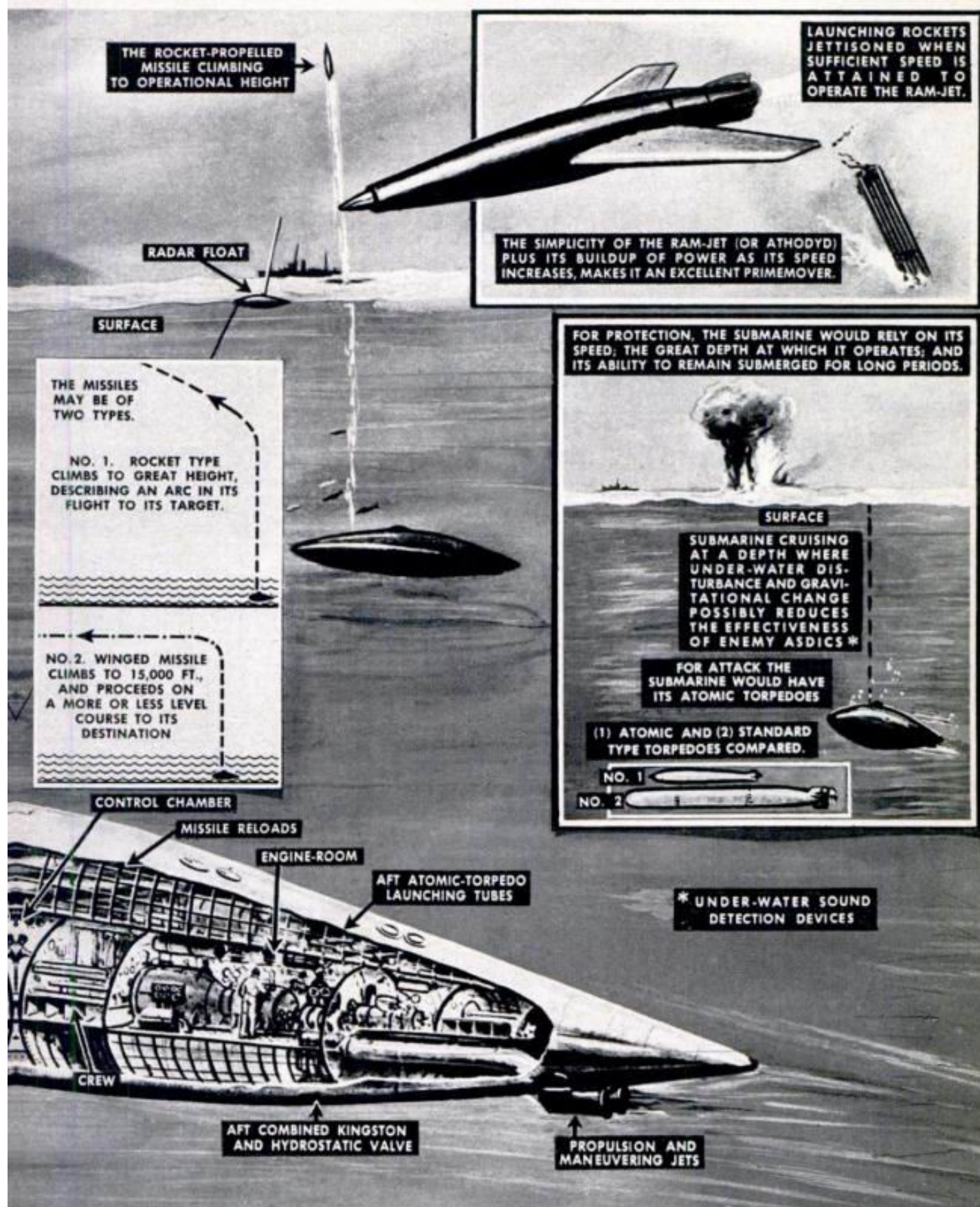


MISSILE JUST LAUNCHED AND RUSHING TO THE SURFACE.



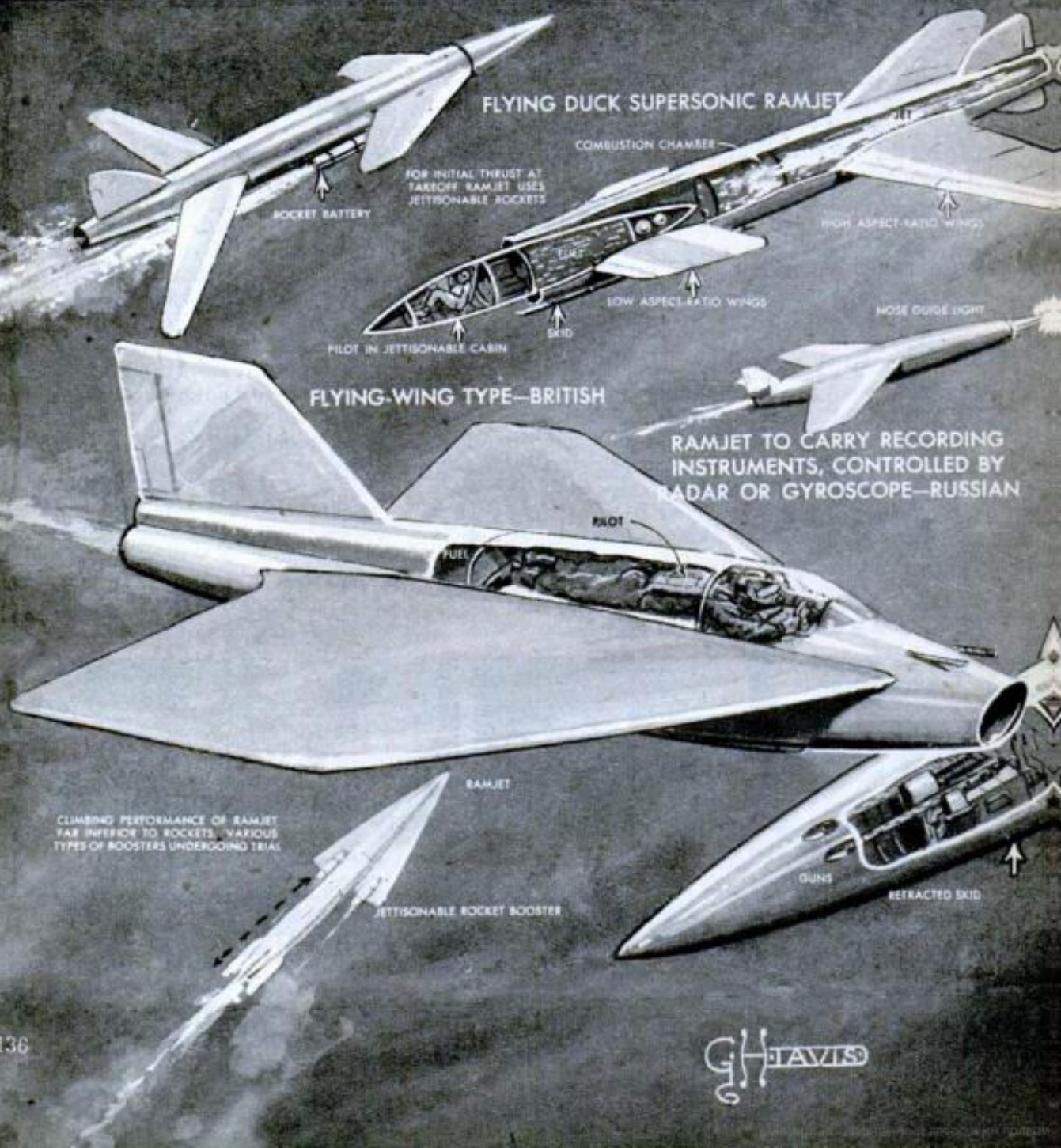
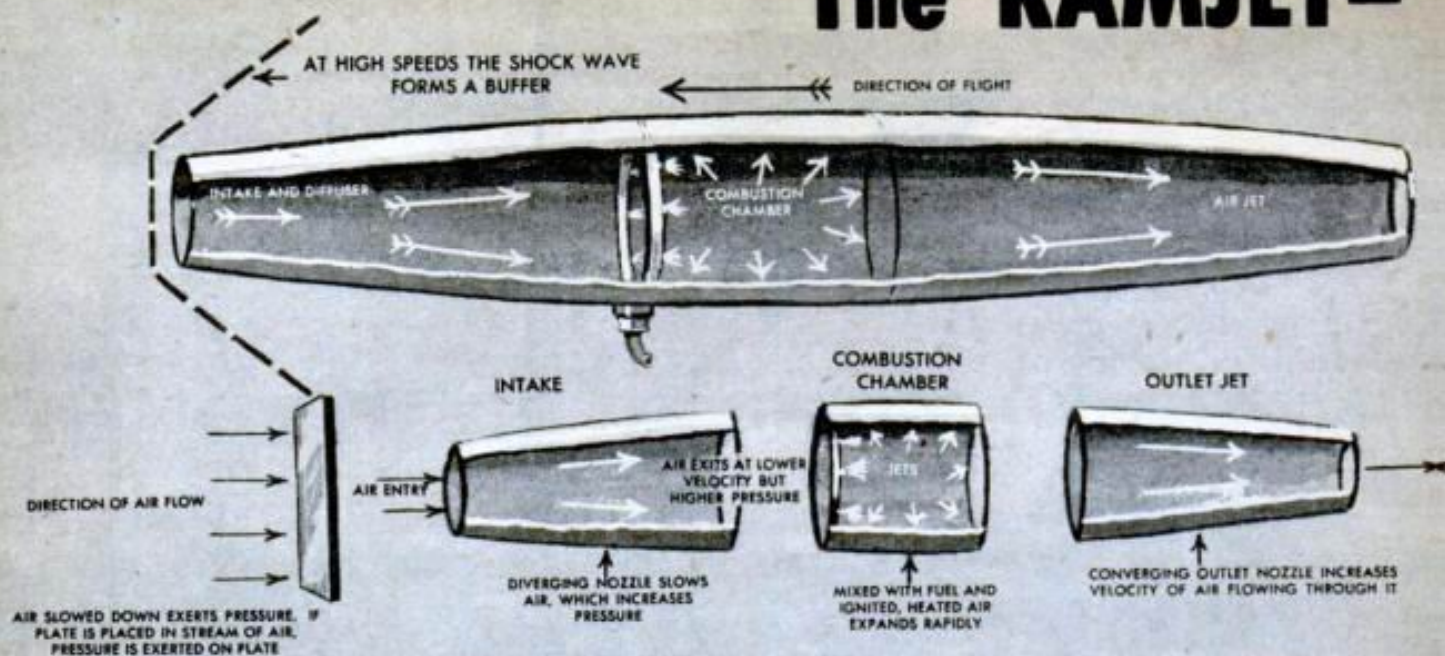
From England come these proposals for waging war from the deep. Submarines powered by jet engines would be equipped with tubes to launch missiles containing atomic war heads. The missile would be expelled from the tube to the surface of the water, where it instantly would release a launching platform from a compartment in the tail. The missile would rise automatically from the platform, which would be left afloat but eventually

ATOMIC MISSILES FOR SUBS

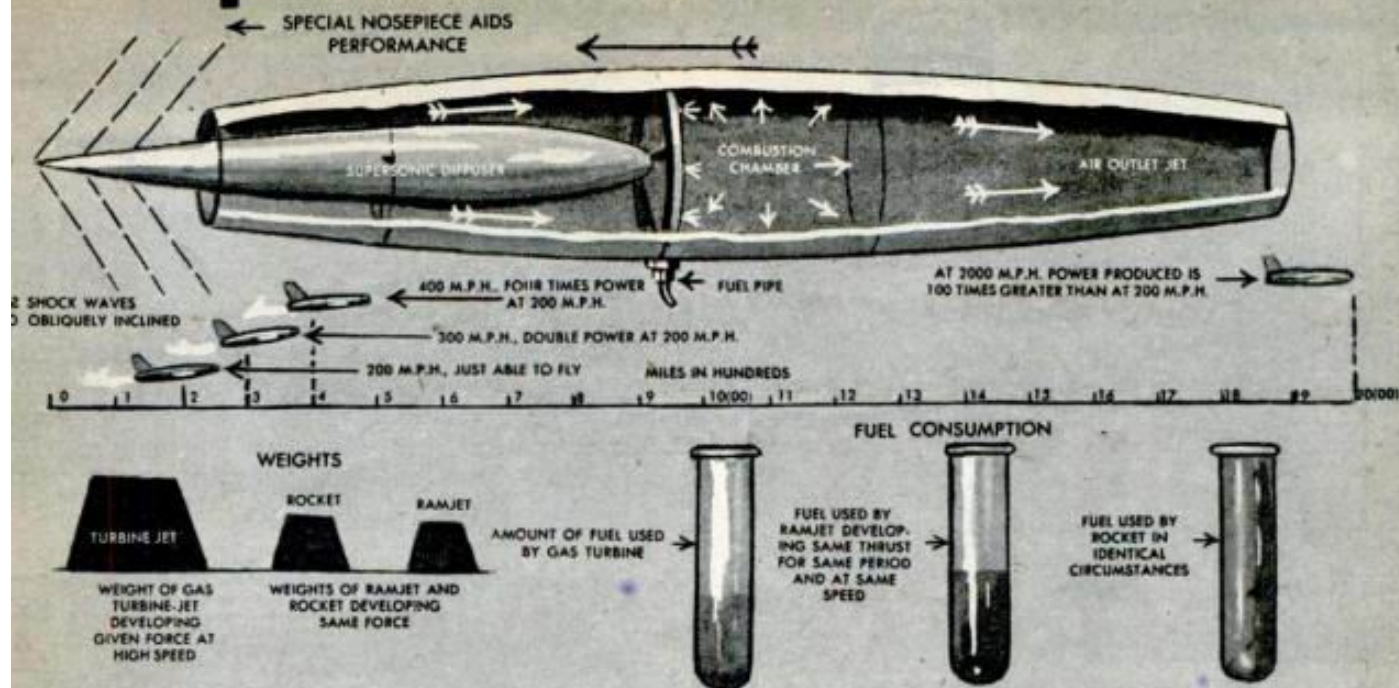


would sink. When the missile is well on its course toward the target, the launching rockets would be jettisoned and wings would unfold from the side. A ram-jet engine then would propel it to the target. Subs also would be equipped with atomic torpedoes, which could be smaller in size than conventional torpedoes. Subs could cruise at high speeds and at depths where effectiveness of the enemy's sound detection would be reduced

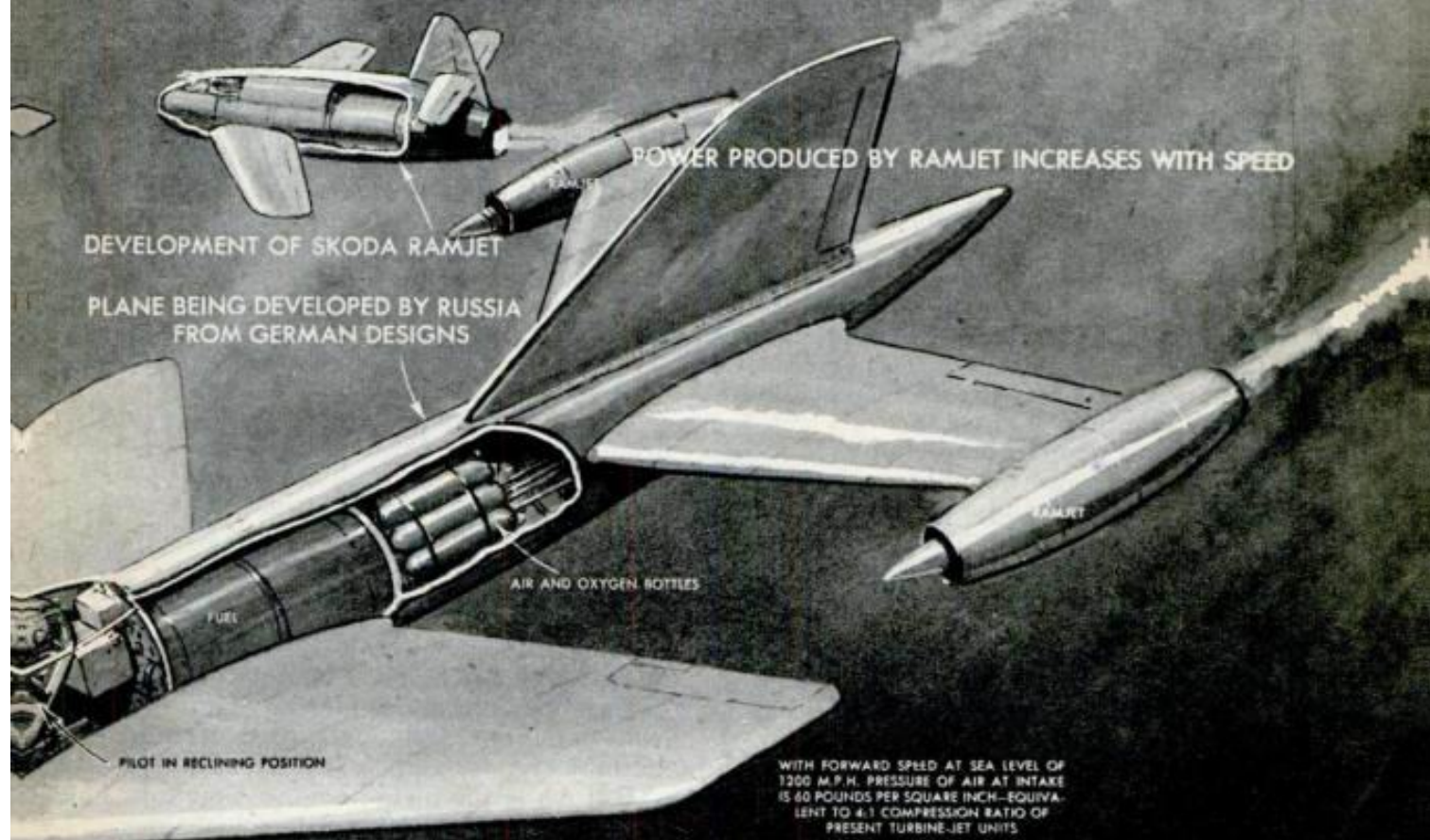
The RAMJET-



Simplest of Prime Movers

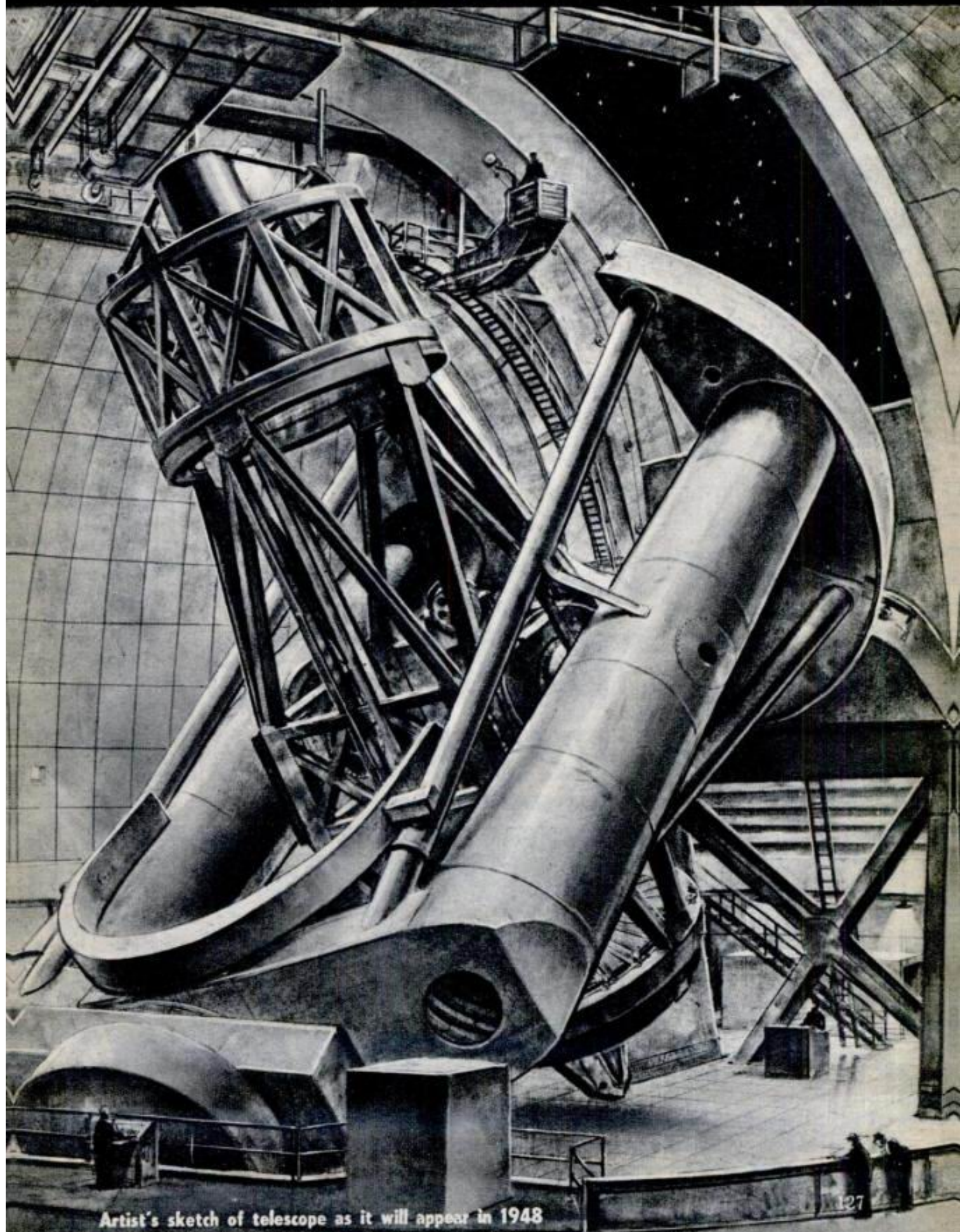


SOME TYPES OF RAMJETS BEING DEVELOPED IN EUROPE



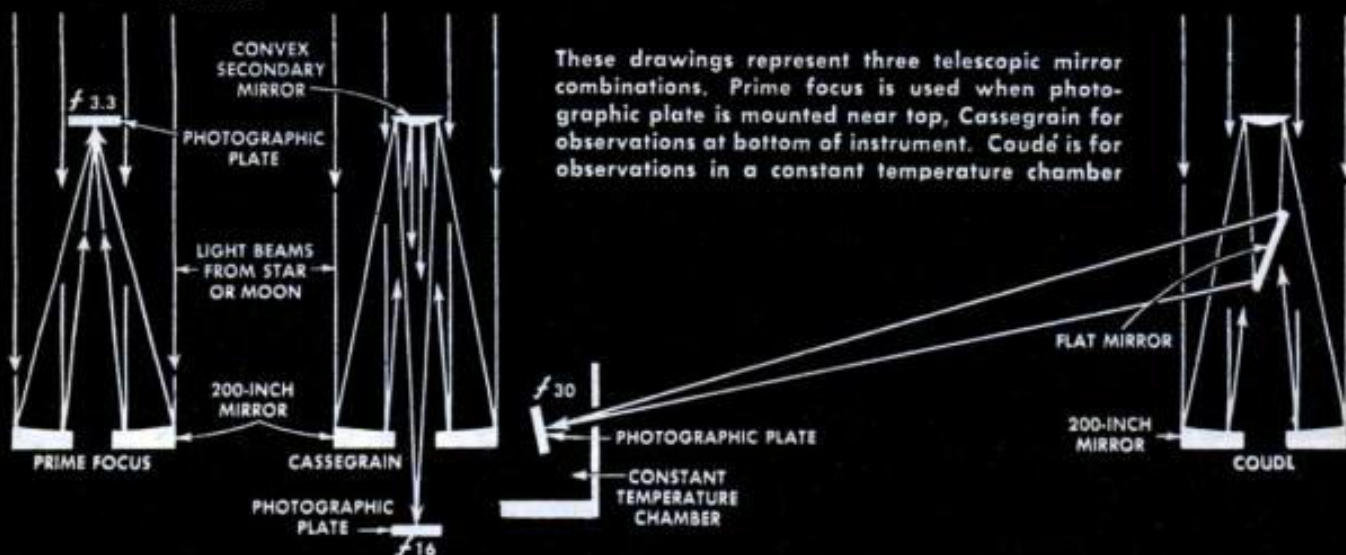
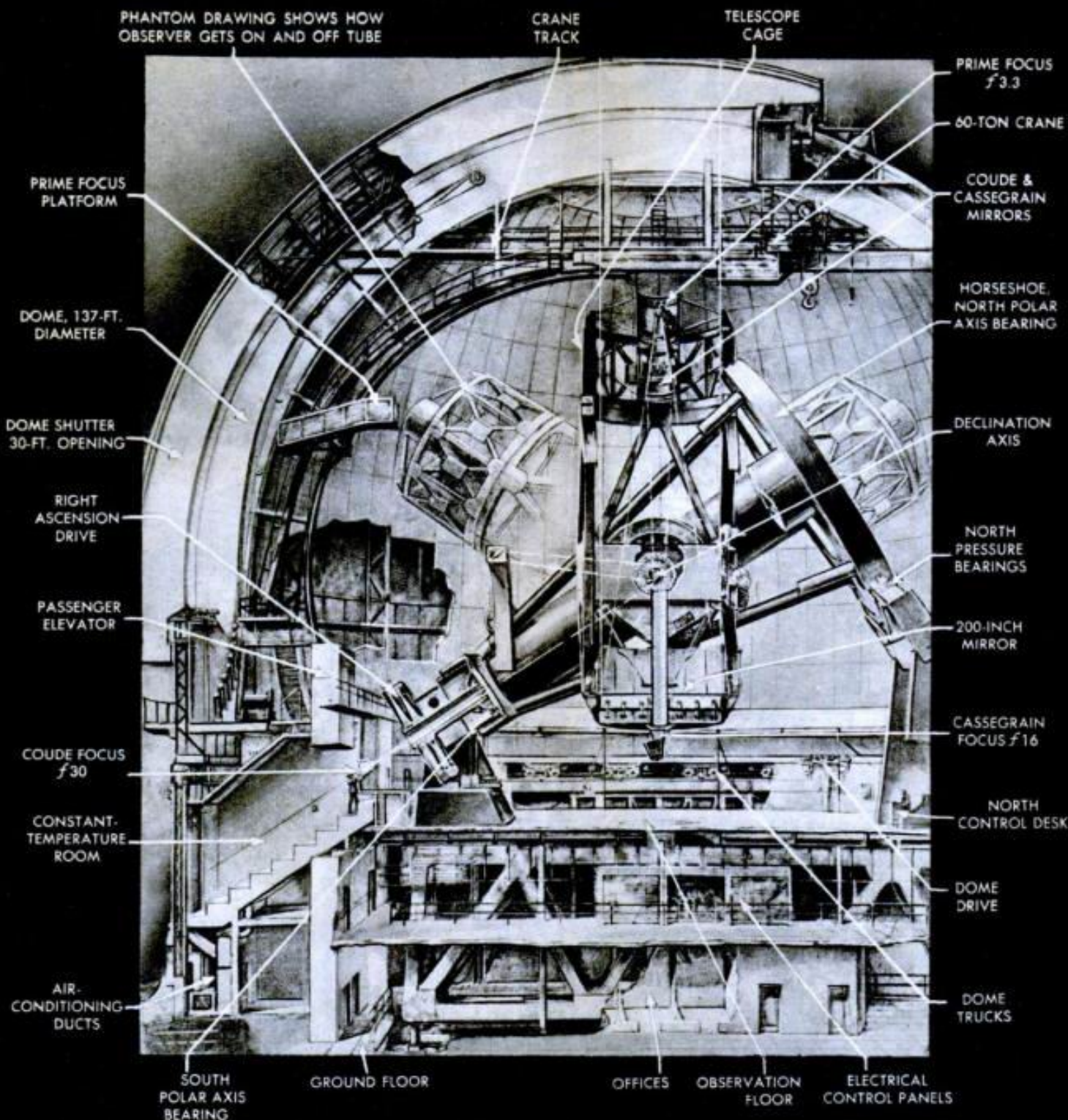
Russia, Britain and the United States have pushed well ahead in developing the ramjet as a possible man-carrying, or at least guided, missile. Known in Europe as athodyd (aero-thermo-dynamic-duct), it is simply a tube into which air is forced by the speed that the tube is driven through the atmosphere. This air is mixed with a fine spray of fuel and fired, issuing from the narrowed tail as a tremendously powerful jet. Unlike gas turbines, in which a compressor raises the pressure of air supplied to the combustion chamber, the ramjet relies on its own speed for this and has no moving parts. Its chief drawbacks at present are excessive fuel consumption, the need for supplementary launching power and a mediocre rate of climb. Now rockets are being used for launchers and as a booster until the ramjet first begins operating at a speed of at least 200 m.p.h. From there on to supersonic speeds its efficiency increases sharply, limited only by combustion factors

WONDER OF THE WORLD



Artist's sketch of telescope as it will appear in 1948

CUTAWAY DRAWING OF 200-INCH TELESCOPE



Energy from outer space



Giant solar collectors nine miles long and three wide are under serious study. By 1995 they may be circling Earth, beaming wireless electricity to your home.

by Richard F. Dempewolf

The year is 1999. You stand on a hillside looking southward at the night sky. Another glittering "star" has just been added to a growing line of them that soon will reach from horizon to horizon like a super Orion's Belt.

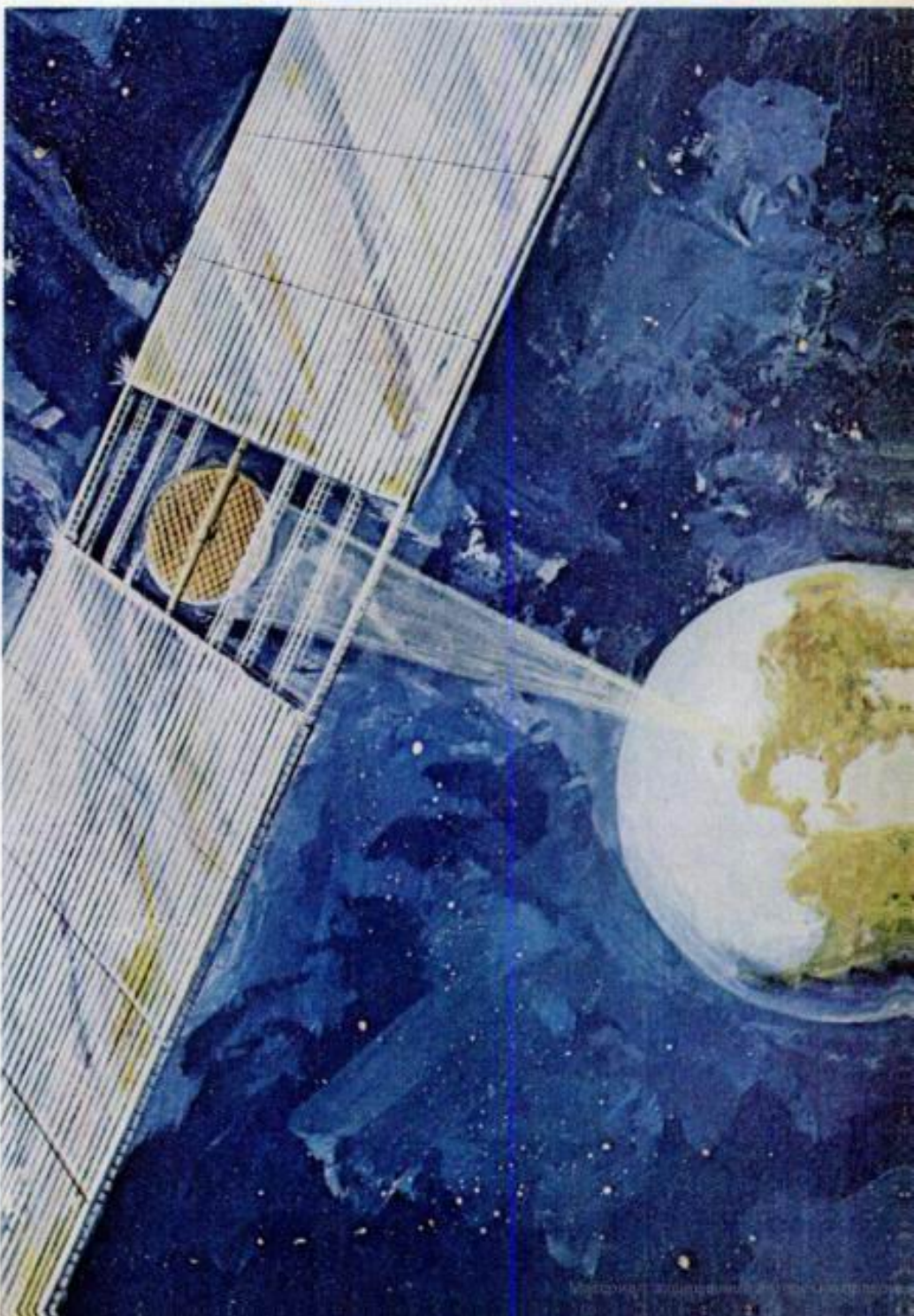
Each of those "stars" is a man-made satellite occupying about 22 square miles of space, hovering motionless in "geosynchronous orbit" (an orbit above the equator in perfect time with Earth's rotation) and beaming to Earth power it collects from the sun. From each, some 10,000 megawatts of electricity (more

than twice the output of the Grand Coulee Dam and enough to power a city the size of New York) are picked up by huge "rectennas" and fed into the nation's power grid.

Cloud nine dreams and schemes? Not according to the people now involved in actual development of the mind-boggling concept.

Recently, Boeing Aerospace's vice president Richard W. Taylor told *Popular Mechanics*: "It is immense, but possible. . . well within our present technology."

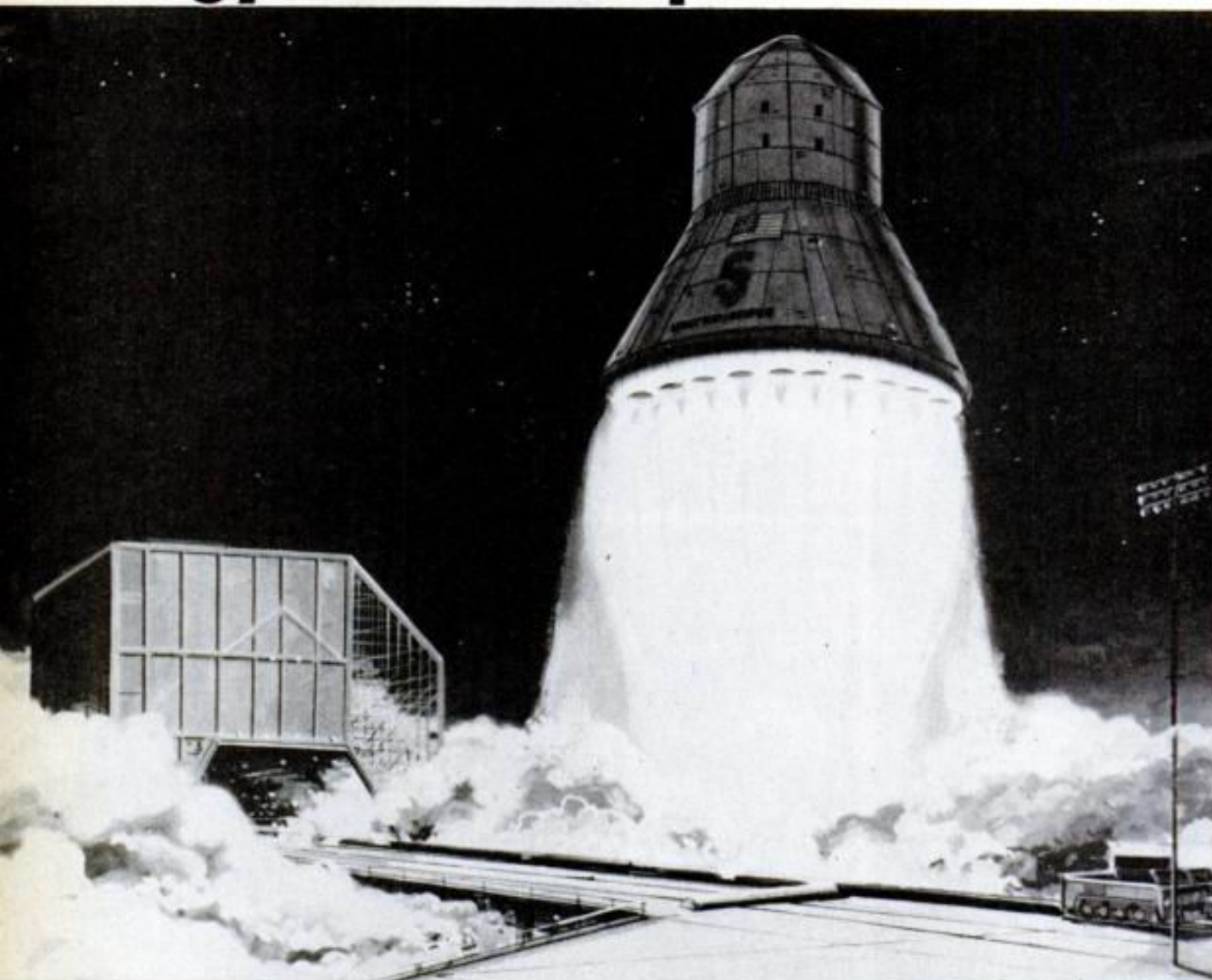
At Grumman Aerospace, Saul Ferdman, director of space program



Four-module power satellite above is the Boeing concept for an orbiting monster nine miles long and three wide. Giant bowls lined with reflective plastic will focus sunlight to a white-hot pinpoint at a receiving cavity in apex of overhead girders. Heat creates steam in a closed-cycle system to drive a generator, and power is beamed to Earth by microwave antenna (far left). Generator unit detail (above, right) shows components under construction. Docked Shuttle shows scale. Girder arms sprout cylindrical "hotels" for crews. Using 22 square miles of solar cells, Grumman's power satellite (right) orbits at 22,300 miles, has no moving parts except adjustable antenna, which directs microwave beam to Earth target.

Energy from outer space

Continued



development, and Richard Kline, manager of space station programs, observed that, "While the Space Solar Power Satellite (SSPS) poses some significant technical challenges, our analyses show them to be less formidable than those we faced at the outset of Project Apollo. . . We might reasonably expect to have the first one in orbit and feeding the electric power grid by 1995."

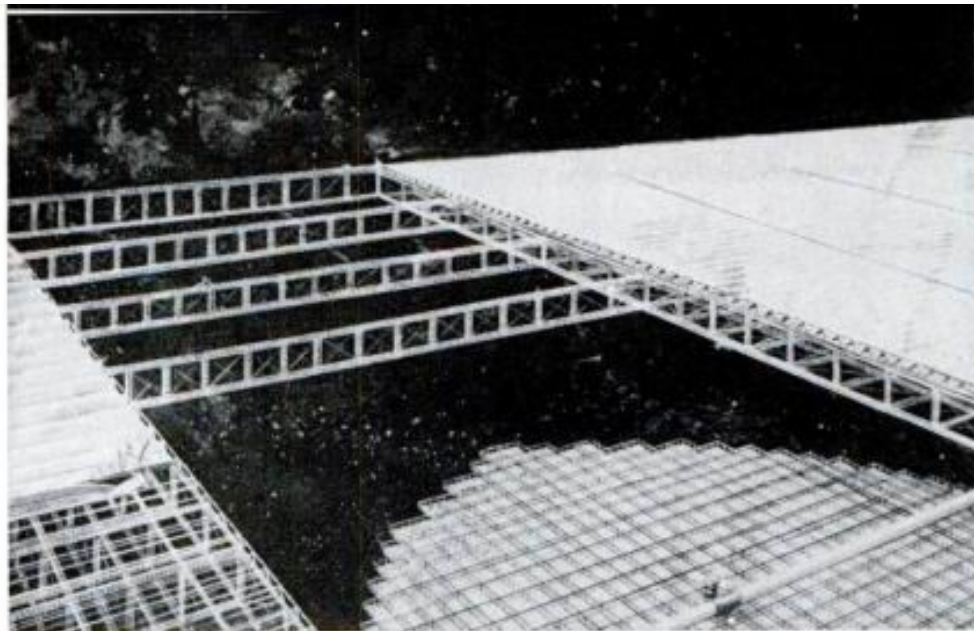
Price would be right

NASA's manager of Satellite Power Systems, S.V. Manson, revealed that "Studies to date indicate that satellite power systems are potentially competitive economically with Earth-based systems." And at the Energy Research and Development Administration, a cautious Dr. Robert Summers told PM that "... the only solar electric approach which seems to offer a possibility of baseload power is the solar satellite power station concept."

The idea of orbiting great solar collectors 22,300 miles in space,



Reusable Heavy Lift Launch Vehicle (top) is Powersat's low Earth orbit freighter for transporting the satellite components to space. The single-stage rocket, with half-million-pound payload capacity, would weigh 22 million pounds at liftoff. Its flight mode would be a once-around orbit with payload deployed on the backside of the orbit. Payload would have its own propulsion unit for distribution and docking. Launch and landing complex at Kennedy Space Center (above) has a huge landing basin for soft powered landing using rockets for deceleration. Launch complexes are on basin's rim.



Antenna for Space Solar Power Satellite is located between two huge panels of solar cells. It tilts, so it always faces the Earth target, while satellite faces the sun.

converting their gathered energy into electricity and transmitting it earthward via microwave or laser, was suggested as early as 1968 by Dr. Peter Glaser of Arthur D. Little Co. in Cambridge, Mass. Reactions were instant and skeptical. Boeing engineers recall that Glaser's ideas were regarded as "something for the next century, if ever." Today, all that has changed. "We are reminded," say Boeing technologists G.R. Woodcock and D.L. Gregory, "of the widely expressed view, in 1960, that man would land on the moon some time after the year 2000."

Two approaches

Since Dr. Glaser first made his startling suggestion, design studies have been under way by a heavy-weight federal and industrial team involving NASA, ERDA, Boeing, Grumman, Jet Propulsion Laboratory, Rockwell, Arthur D. Little, Raytheon, Spectrolab, Econ and others.

Details of two separate approaches have been worked out meticulously. One, developed by the Grumman-Arthur D. Little group, is the SSPS, using a photovoltaic process in which solar cells convert sunlight directly to usable electric power in the same way they've provided power for nearly every spacecraft and satellite to date. The other—"Power-sat"—explored by the NASA-Boeing researchers, uses a thermal concentrator and heat engine system. This involves arrays of gigantic hexagonal bowl-shaped reflectors, each about three miles from rim to rim, focusing sunlight on a receiving cavity mounted high above the bowls where the intense heat turns a fluid to steam and drives a mechanical turbogenerating system.

Why bother putting all that stuff in space when solar powerplants could just as well be located on sun-drenched deserts? Boeing's Ralph Nansen explains that the output of a solar collector in space is about six times what it would be at the best location on Earth. Due to day and night cycles down here, huge storage capacities would be required, and the remoteness of deserts would mean extensive transmission lines.

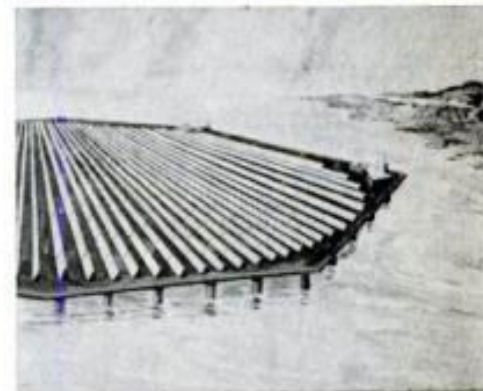
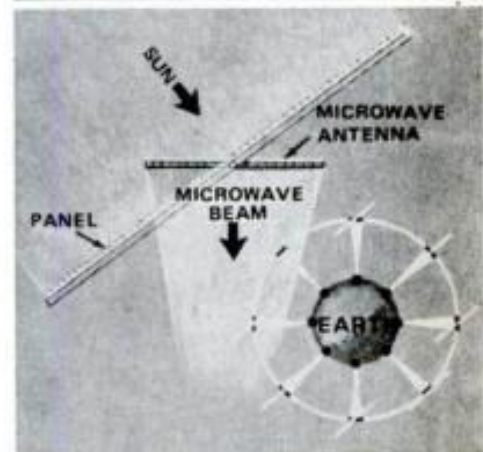
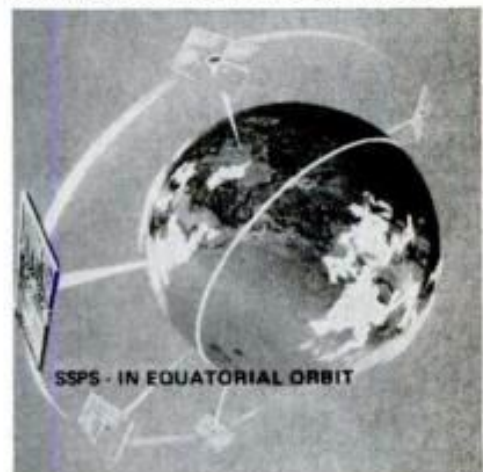
On the other hand, a satellite in geosynchronous orbit is exposed to continuous sunlight more than 99 percent of the time, and power could be beamed where needed. The only inactivity would involve minutes during solstice periods when the collectors would pass through Earth's shadow.

To comprehend even remotely the vastness of these gigantic space islands, you'd have to climb aboard one and look around. From one end of the SSPS, the view would reach out across seemingly endless miles of glaring reflective corrugations, diminishing into star-studded blackness. Out there, other islands in the great energy archipelago would shine like links in a golden chain, disappearing where it curled behind Earth's rim.

Two huge panels

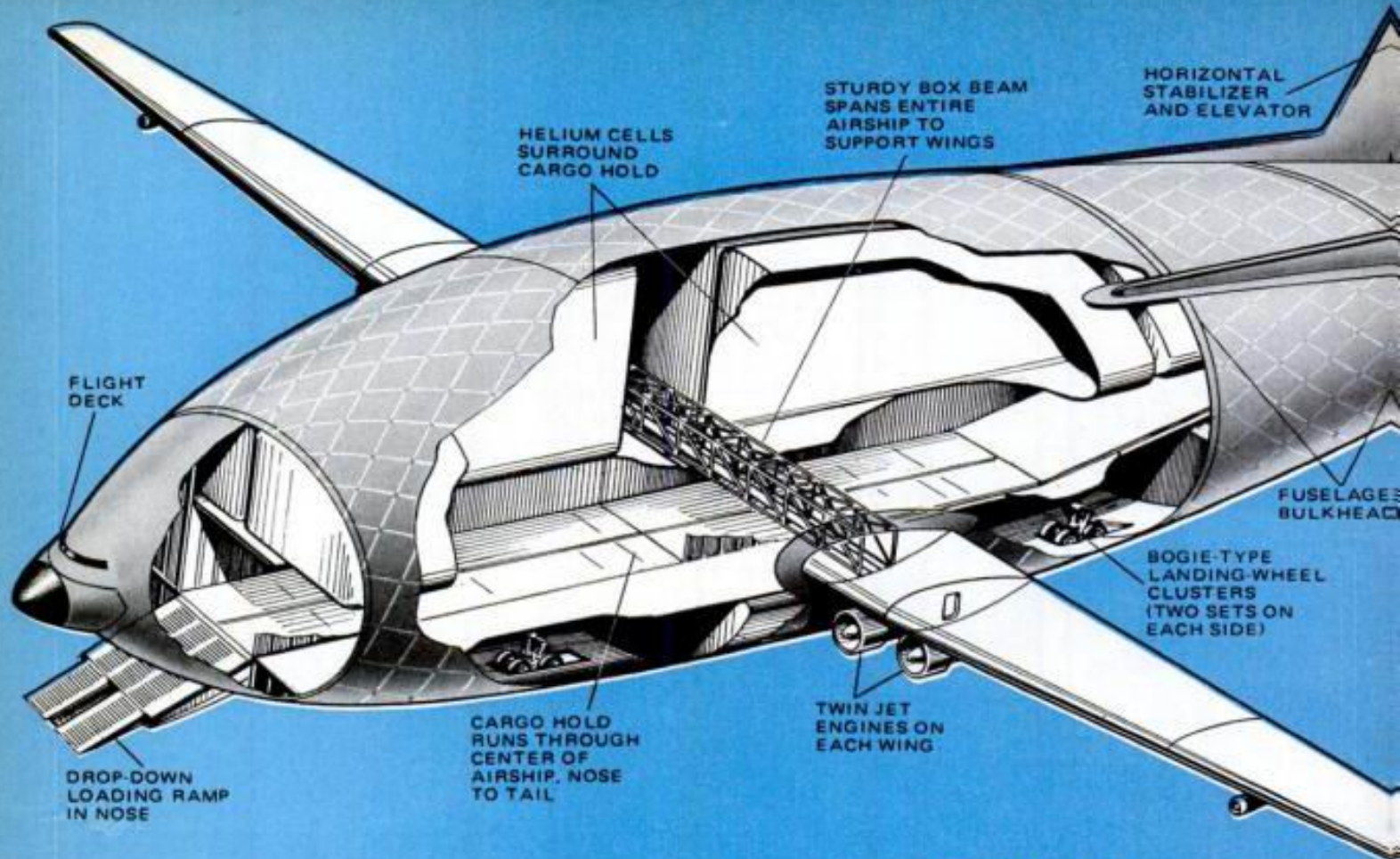
Activate your jet backpack and levitate yourself a hundred or so feet above the surface of the vast solar panel, and you'll see that the station itself actually is made up of two rectangular panels, each about $3\frac{1}{2}$ miles long by 3 wide, and 600 feet deep, connected by a few main girders and a great mast. Located between the panels is the half-mile-wide disc of the adjustable microwave transmitting antenna.

Satellite chain in operation (top) shows how SSPS system beams power directly to specific targets as units orbit in synch with Earth's rotation. Cross section of satellite (center) shows solar collectors at right angle to sun, while antenna tilts to hold beam on rectenna target. Proposed plan (bottom) is for offshore rectenna to convert microwave energy to a.c. electricity and feed it to power grid ashore.



Mounted on each huge panel, reflective ridges march away like waves, giving it the appearance of a shiny metal washboard. Oriented to face the sun in perpetuity, endless arrays of solar cells lie along the surface of each depression in the washboard. Slopes of the ridged corrugations are covered with reflectively coated sheet plastic. The solar cells are bathed in direct sunlight as well as the concentrated light that is focused on them by reflectors—which more than doubles the

(Please turn to page 152)

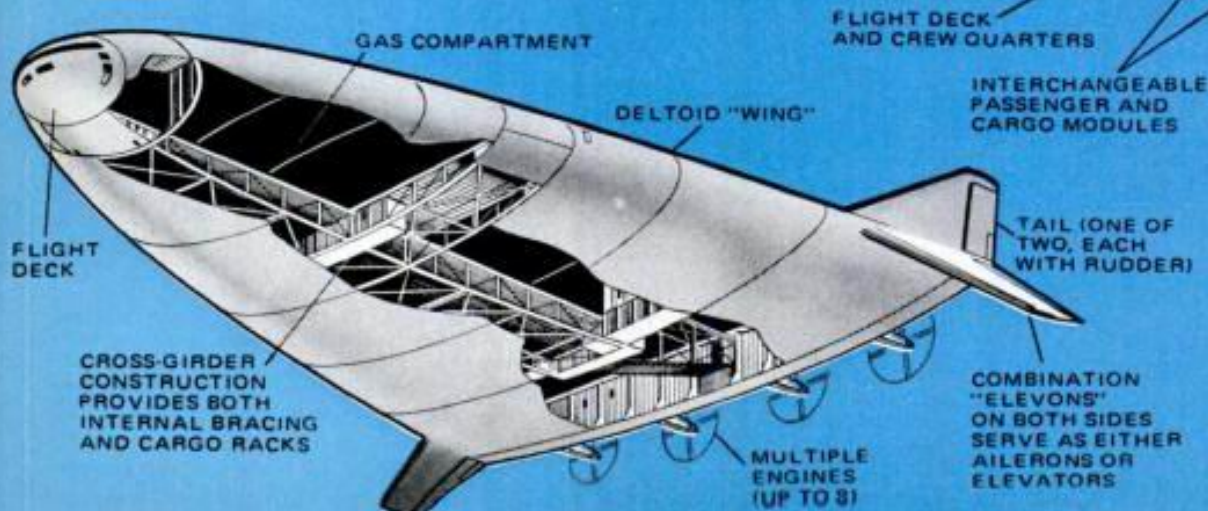


One of biggest and most unusual hybrid airships proposed is *Megalifter* above. Half airplane and half dirigible, it would be 650 feet long with a wingspan of 530 feet. It would rely on helium for heavy-lift capacity and jet engines for high-speed cargo delivery.

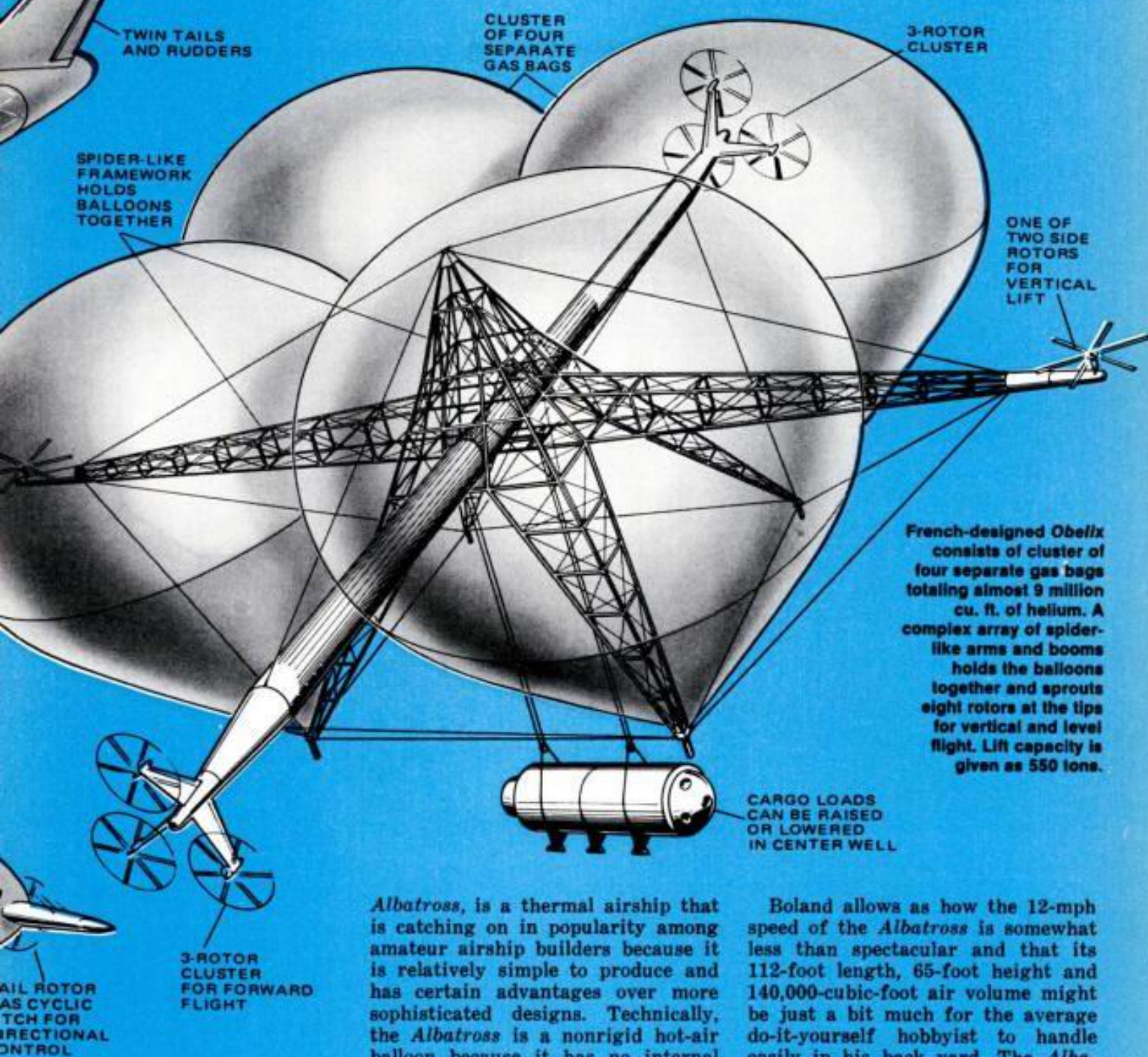
OVERALL LENGTH: 472.8 FEET
MAX. HULL DIA.: 97.7 FEET



Wing-shaped *Dynairship*, like *Megalifter* above, combines gas lift with aerodynamic lift for both speed and range. Ship is powered by pusher props along rear end. Navy is considering design for long-range surveillance of enemy submarines.



Big boom in gas bags



French-designed Obelisk consists of cluster of four separate gas bags totaling almost 9 million cu. ft. of helium. A complex array of spider-like arms and booms holds the balloons together and sprouts eight rotors at the tips for vertical and level flight. Lift capacity is given as 550 tons.

Albatross, is a thermal airship that is catching on in popularity among amateur airship builders because it is relatively simple to produce and has certain advantages over more sophisticated designs. Technically, the *Albatross* is a nonrigid hot-air balloon because it has no internal framing and uses hot air for lift, not a gas like helium. It relies on propane burners to supply the heat.

Power makes the difference

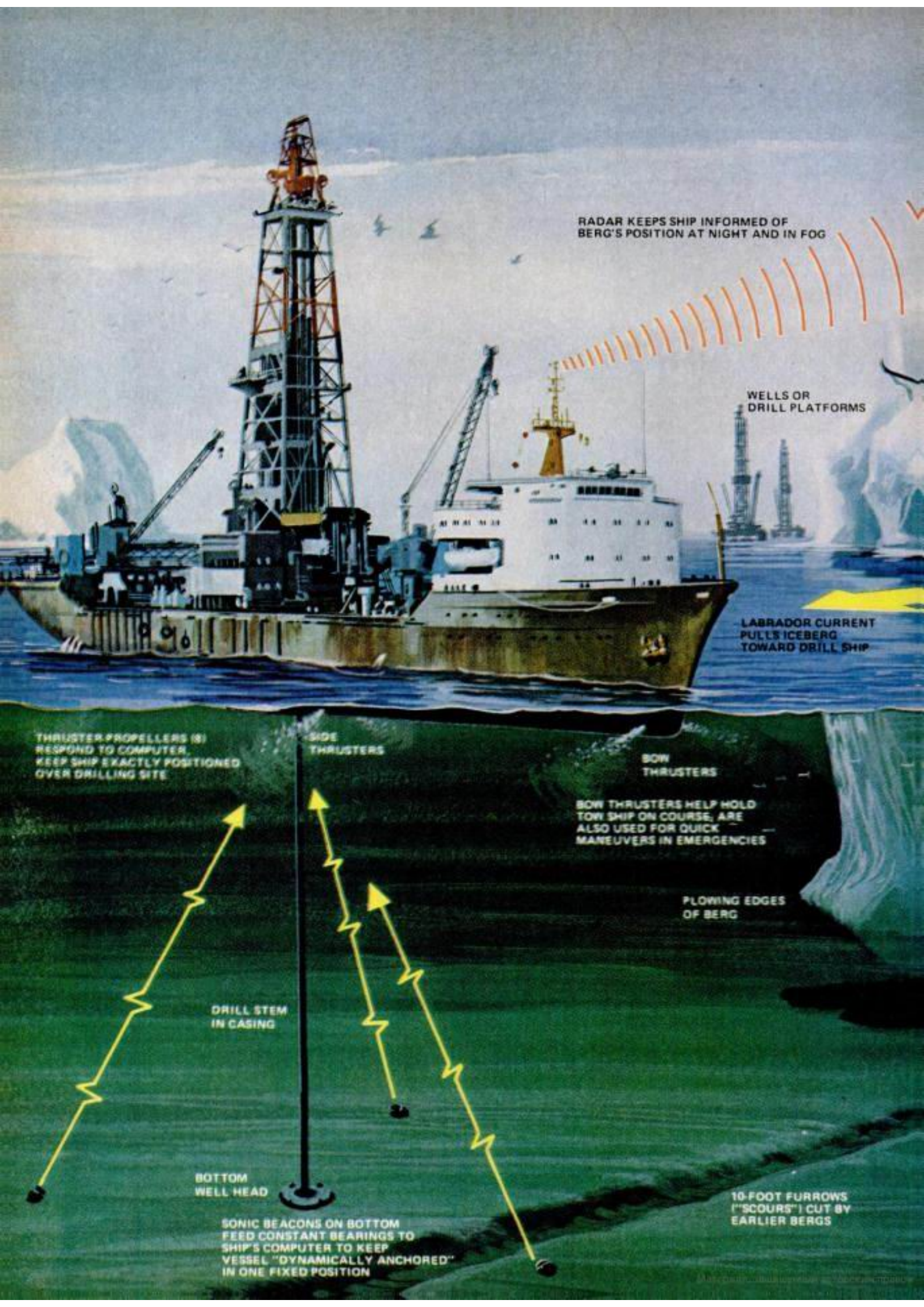
What makes the *Albatross* an airship—aside from its elongated streamlined teardrop shape—is that it is *powered*. Mounted on the rear of the quaintly traditional wicker gondola is a modern 40-hp, shrouded-prop Rockwell powerplant originally made for propeller-driven swamp boats. With it Brian can make up to 12 mph headway in more or less the direction he wants to go, instead of drifting along at the mercy of prevailing winds as unpowered free balloons must do.

Boland allows as how the 12-mph speed of the *Albatross* is somewhat less than spectacular and that its 112-foot length, 65-foot height and 140,000-cubic-foot air volume might be just a bit much for the average do-it-yourself hobbyist to handle easily in his back yard. The *Albatross* is primarily a test bed for experimentation, however, and many modifications are planned.

First, Brian is going to try more power—a 95-hp Subaru engine from which he expects to get 25 mph, or double his present speed. Next year, he plans to scale down the *Albatross* to roughly half its current size, which he says will be much more manageable—the present version requires about eight ground crewmen and carries four; the new half-scale ship will be launched and piloted by two—Brian and his wife, Kathy. Its gondola will be designed to fit a car-top carrier and hold the folded-up gas bag, flight gear and camping

(Please turn to page 130)

rigid-framed dirigible at left in facing page is conventional in appearance, but has unusual new features. Side rotors pivot up or down for vertical or forward flight. In addition, a tail rotor with helicopter-like cyclic pitch helps to provide directional control. Designed by Lightspeed USA, Inc., LS-80 could be 473 feet long—twice that of 747 jumbo jet. Circular inset shows how passengers sit sideways to enjoy scenic views through large cabin windows.



RADAR KEEPS SHIP INFORMED OF
BERG'S POSITION AT NIGHT AND IN FOG

WELLS OR
DRILL PLATFORMS

LABRADOR CURRENT
PULLS ICEBERG
TOWARD DRILL SHIP

THRUSTER PROPELLERS (8)
RESPOND TO COMPUTER,
KEEP SHIP EXACTLY POSITIONED
OVER DRILLING SITE

SIDE
THRUSTERS

BOW
THRUSTERS

BOW THRUSTERS HELP HOLD
TOW SHIP ON COURSE, ARE
ALSO USED FOR QUICK
MANEUVERS IN EMERGENCIES

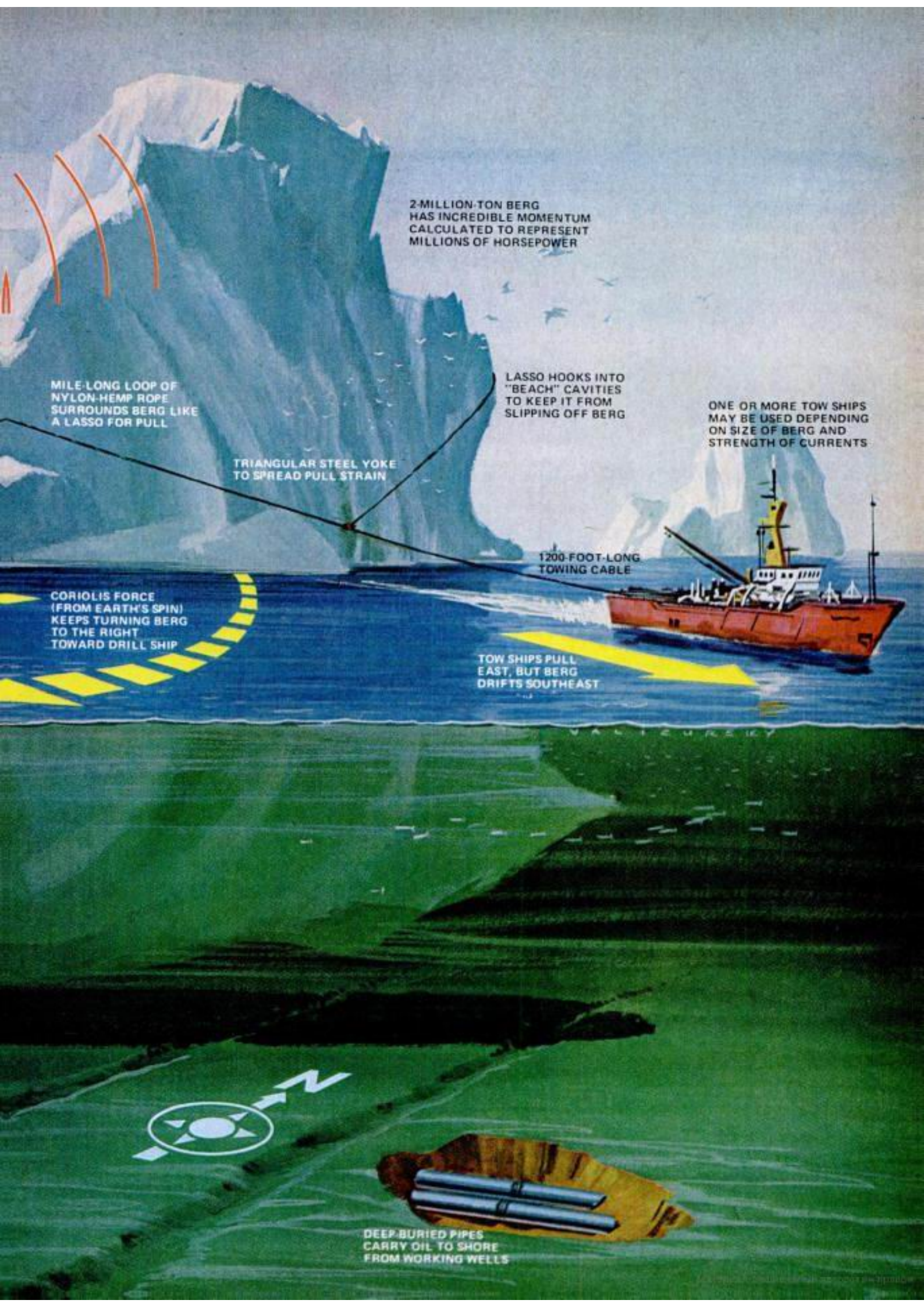
PLOWING EDGES
OF BERG

DRILL STEM
IN CASING

BOTTOM
WELL HEAD

SONIC BEACONS ON BOTTOM
FEED CONSTANT BEARINGS TO
SHIP'S COMPUTER TO KEEP
VESSEL "DYNAMICALLY ANCHORED"
IN ONE FIXED POSITION

10-FOOT FURROWS
("SCOURS") CUT BY
EARLIER BERGS



2-MILLION-TON BERG
HAS INCREDIBLE MOMENTUM
CALCULATED TO REPRESENT
MILLIONS OF HORSEPOWER

MILE-LONG LOOP OF
NYLON-HEMP ROPE
SURROUNDS BERG LIKE
A LASSO FOR PULL

LASO HOOKS INTO
"BEACH" CAVITIES
TO KEEP IT FROM
SLIPPING OFF BERG

ONE OR MORE TOW SHIPS
MAY BE USED DEPENDING
ON SIZE OF BERG AND
STRENGTH OF CURRENTS

TRIANGULAR STEEL YOKE
TO SPREAD PULL STRAIN

1200-FOOT-LONG
TOWING CABLE

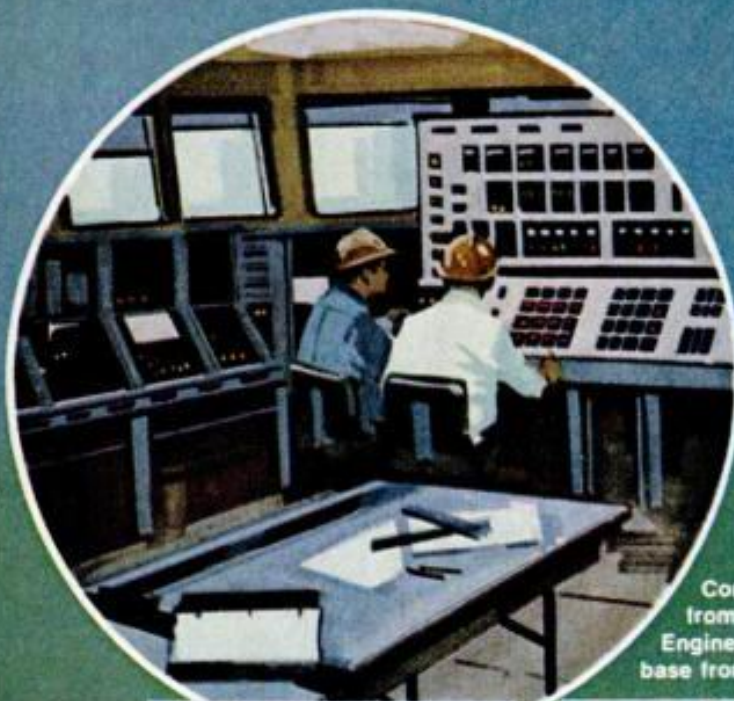
CORIOLIS FORCE
(FROM EARTH'S SPIN)
KEEPS TURNING BERG
TO THE RIGHT
TOWARD DRILL SHIP

TOW SHIPS PULL
EAST, BUT BERG
DRIFTS SOUTHEAST

DEEP-BURIED PIPES
CARRY OIL TO SHORE
FROM WORKING WELLS

Towing the base section on the world's biggest barge to its launch site 15 miles south of the mouth of the Mississippi River in the Gulf of Mexico was a tricky job.

After flooding one end of the barge so it was tilted 3° down, hydraulic jacks raised one end of the base section, causing it to slide off slippery tracks into the water.

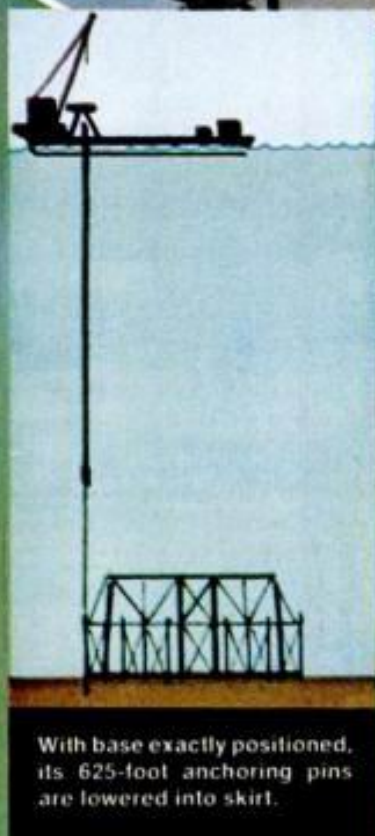


A thousand feet below the floor of the Gulf of Mexico lie 100 million barrels of crude oil. A thousand feet above the floor works a group of men whose dream is to tap that oil.

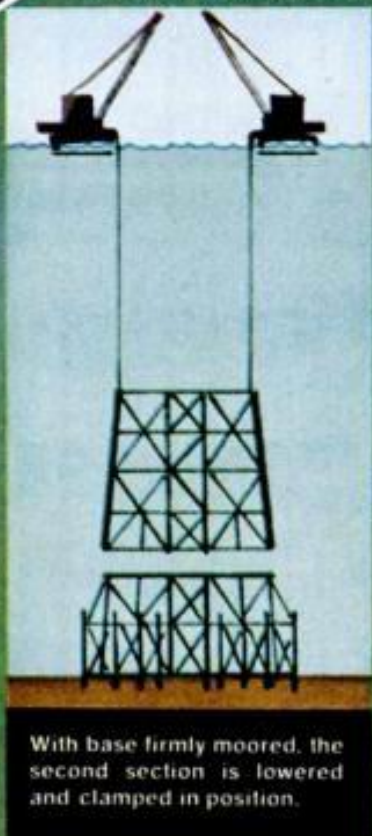
Until now it's been impossible. The technology wasn't there to build a giant offshore drilling platform whose feet would be stuck in clay 1000 feet below the surface. But those times have passed, and oil engineers are stretching the state of their art beyond belief.

Today, a super rig is under construction in unpredictable waters just 15 miles south of the Mississippi River mouth. Soon an amazing 62

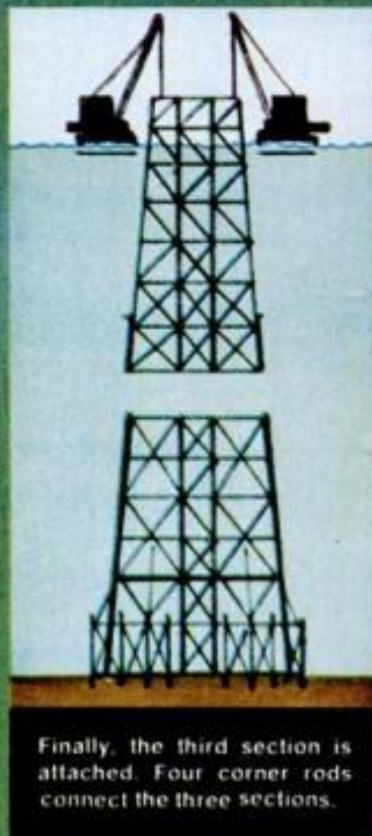
Control panels (left) give positional information from a computer located on the on-site barge. Engineers can operate derricks to position the platform base from control room by following computer displays.



With base exactly positioned, its 625-foot anchoring pins are lowered into skirt.



With base firmly moored, the second section is lowered and clamped in position.



Finally, the third section is attached. Four corner rods connect the three sections.

Cables of steel 3½ inches in diameter were rigged from two derrick barges. Skirt tubes on the base were flooded to a predetermined level to give slight negative buoyancy.

When erected, drilling rigs on the Cognac platform will make its superstructure 15 feet taller than the Empire State Building.

Oil engineers are pushing technology to the limit as they build the world's largest offshore oil platform in 1000 feet of water.

by Dan Fales

HOW OILMEN ARE LAUNCHING

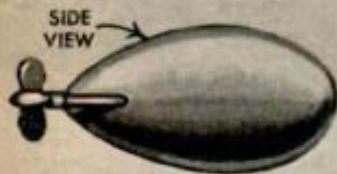
SUPER RIG

More than 60 separate wells will be sunk from the rig to tap gas and oil from the 35-square-mile area.





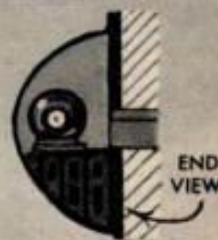
THIRTEEN MOTORS TO PORT AND STARBOARD, EACH RECEIVING POWER FROM A CENTRAL TURBO-GENERATING PLANT



SIDE VIEW



PLAN VIEW OF A NACELLE

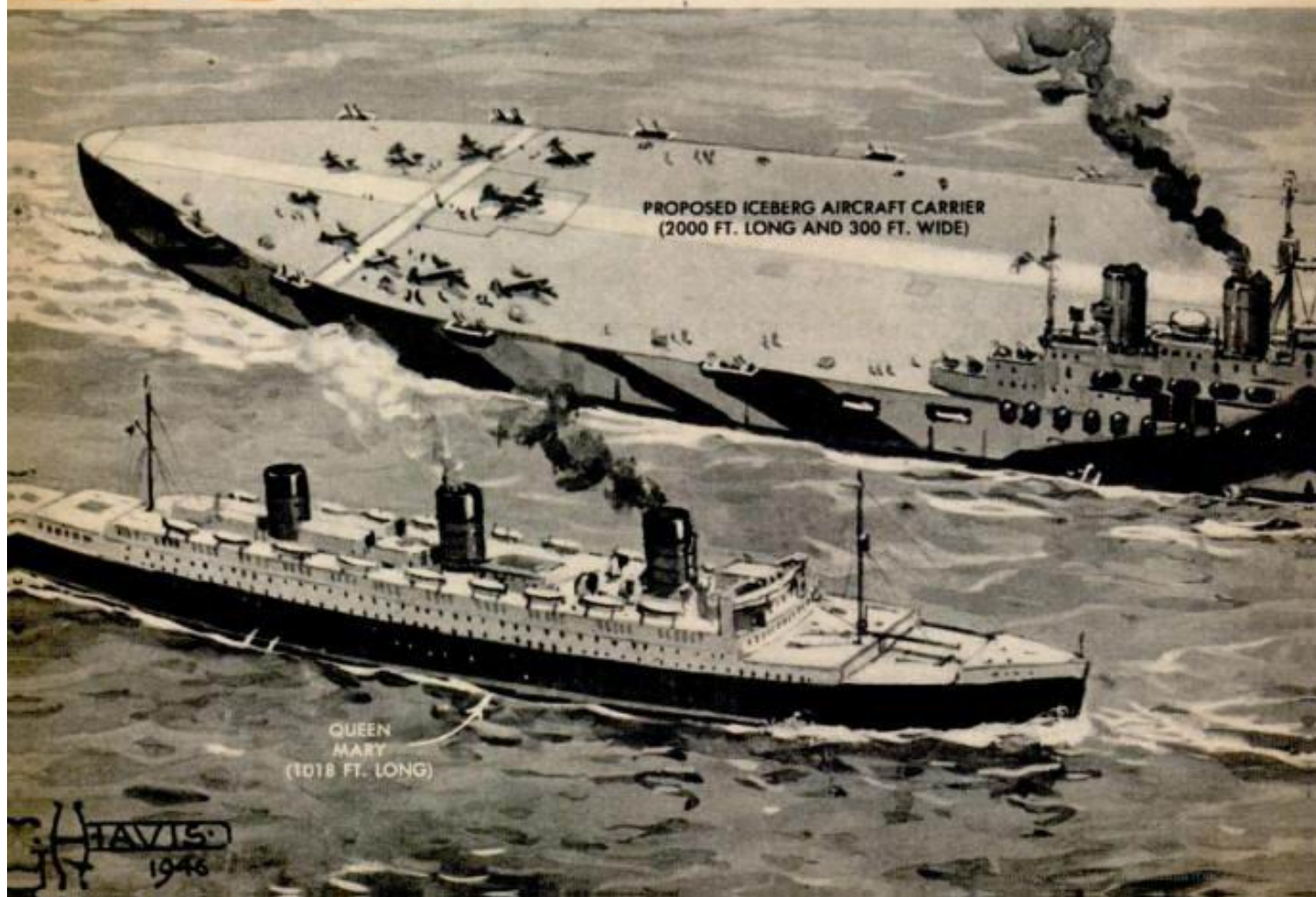


END VIEW

ICE CUBE FLATTOP

Designed by British to Fight Subs

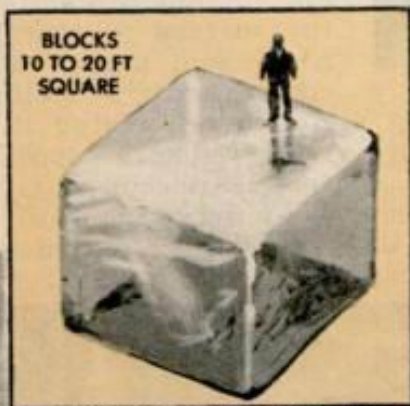
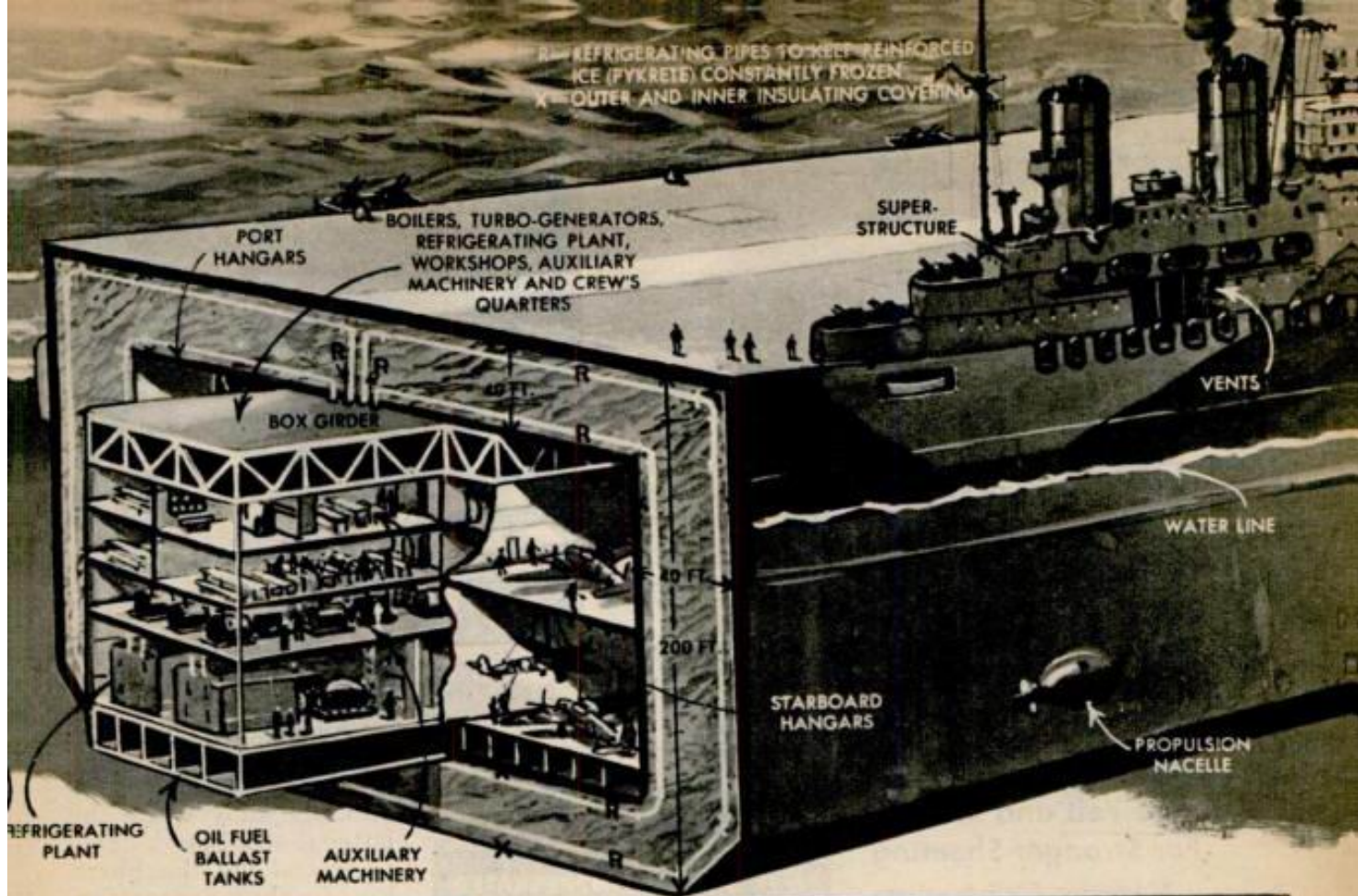
Habakkuk Project was the British designation for a 2,000,000-ton torpedoproof aircraft carrier to be built of blocks of reinforced ice. The iceberg carrier, more than a third of a mile in length, was designed to fight subs and to provide air cover for the invasion of Europe. Plans called for walls 40 feet thick, laced with refrigerating pipes and covered with insulating material. The ice blocks, dubbed Pykrete, were reinforced with 14 percent wood pulp because ice alone was too brittle. Thirteen nacelles on each side were to provide propulsion units with each propeller driven by an electric motor. A 1000-ton model was built on a Canadian lake. The project, sanctioned by Winston Churchill, was abandoned only after the war against the U-boats turned in the Allies' favor in 1943.



PROPOSED ICEBERG AIRCRAFT CARRIER
(2000 FT. LONG AND 300 FT. WIDE)

QUEEN
MARY
(1018 FT. LONG)

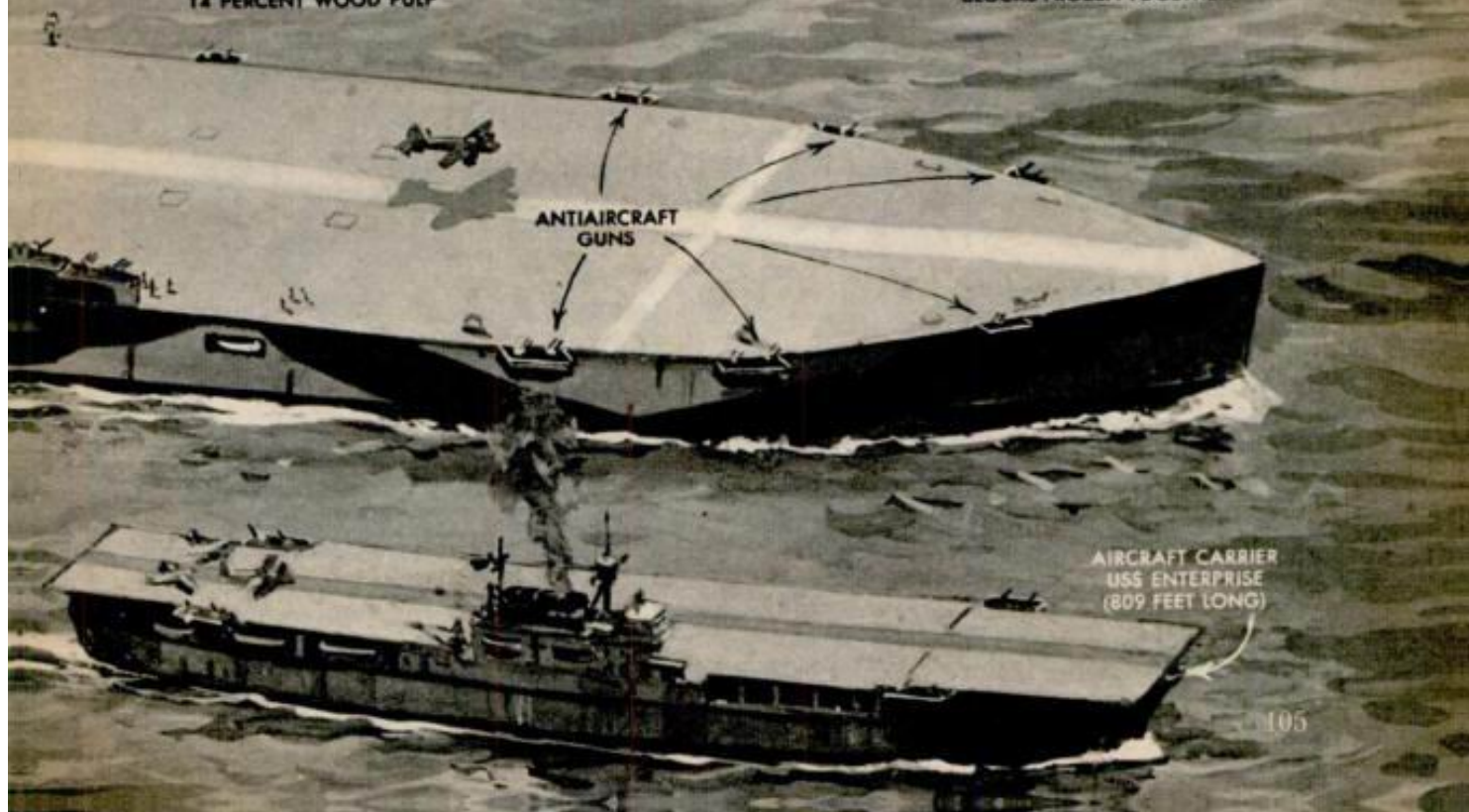
R- REFRIGERATING PIPES TO KEEP REINFORCED
ICE (PYKRETE) CONSTANTLY FROZEN
X- OUTER AND INNER INSULATING COVERING

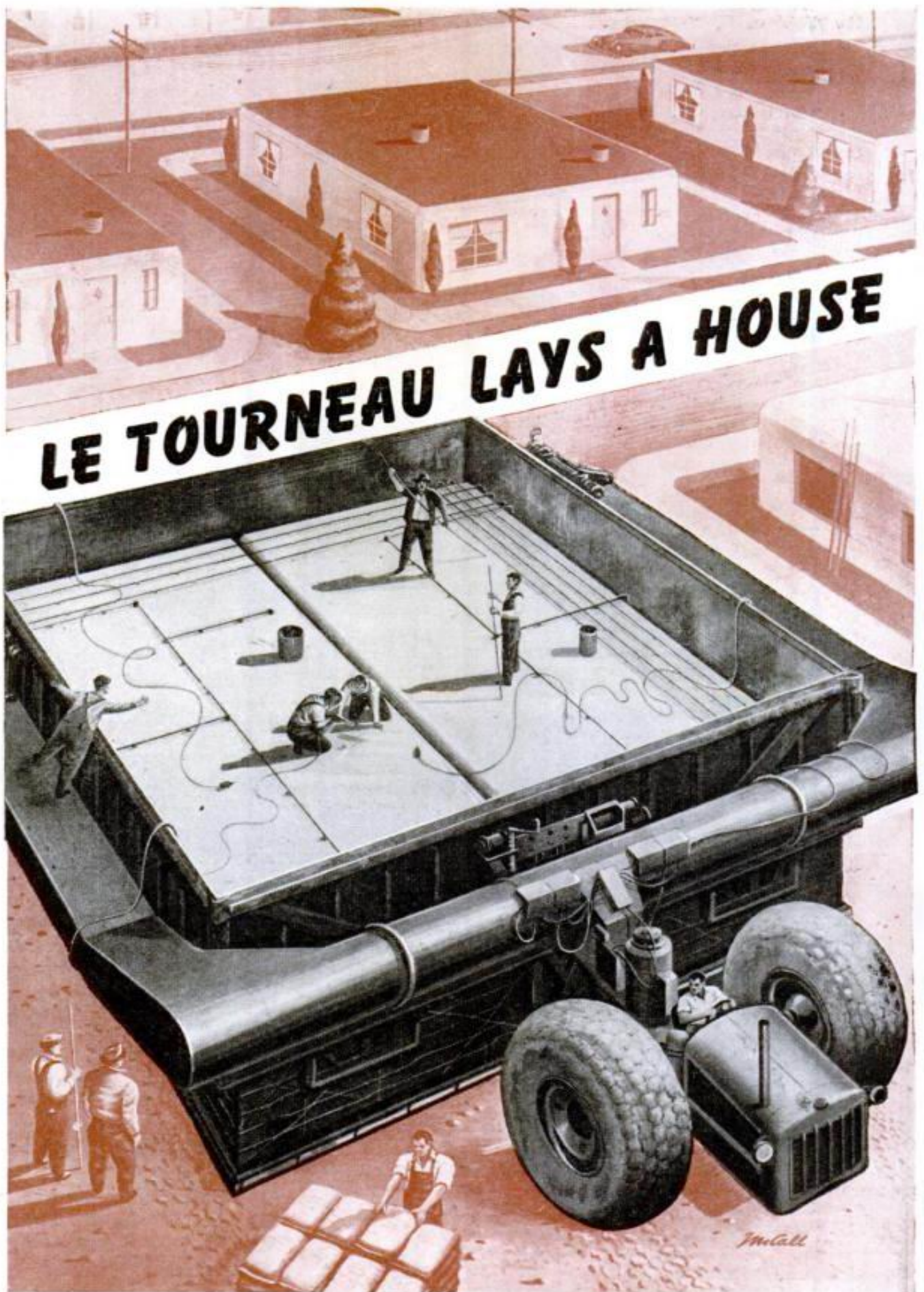


PYKRETE IS 86 PERCENT ICE AND
14 PERCENT WOOD PULP



IT WAS TO BE BUILT OF PYKRETE
BLOCKS FROZEN TOGETHER





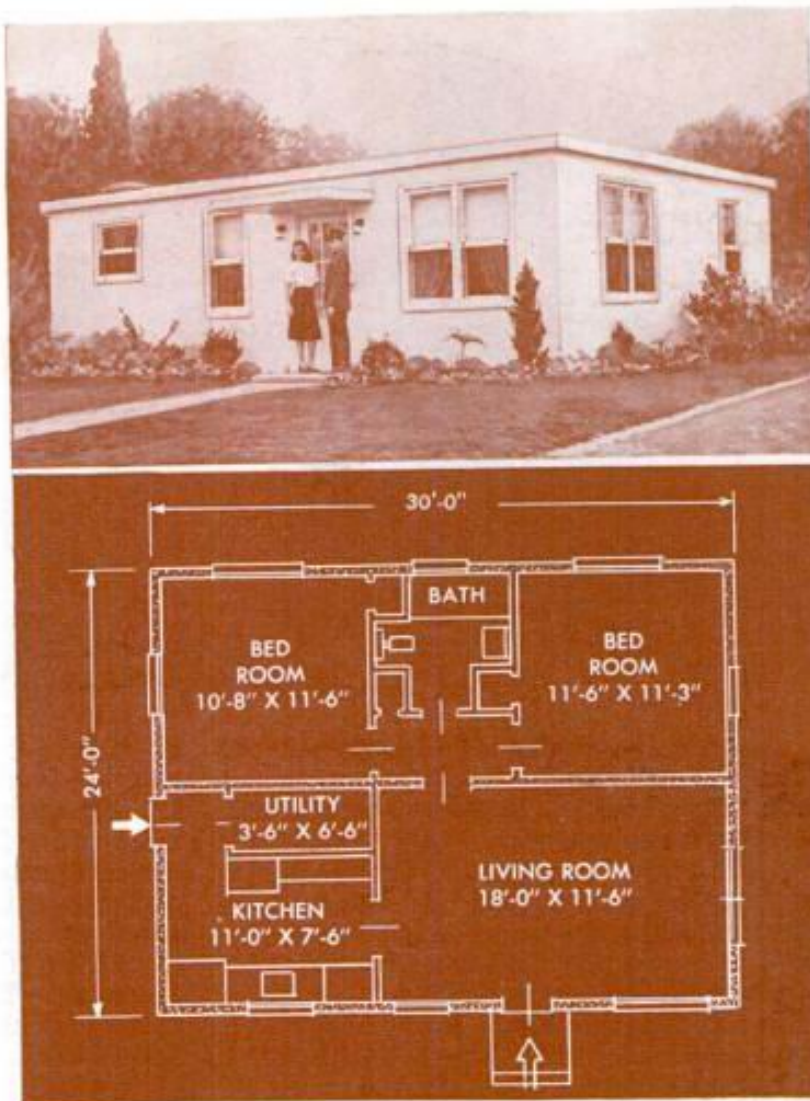
Like a giant chicken laying eggs, this huge machine forms and gently sets in place complete concrete homes. Roof and walls, with allowances for doors and windows, are poured after inner and outer forms are built and steel reinforcing is installed. After setting 24 hours, the house is carried to its site by the robot contractor

By William F. McDermott

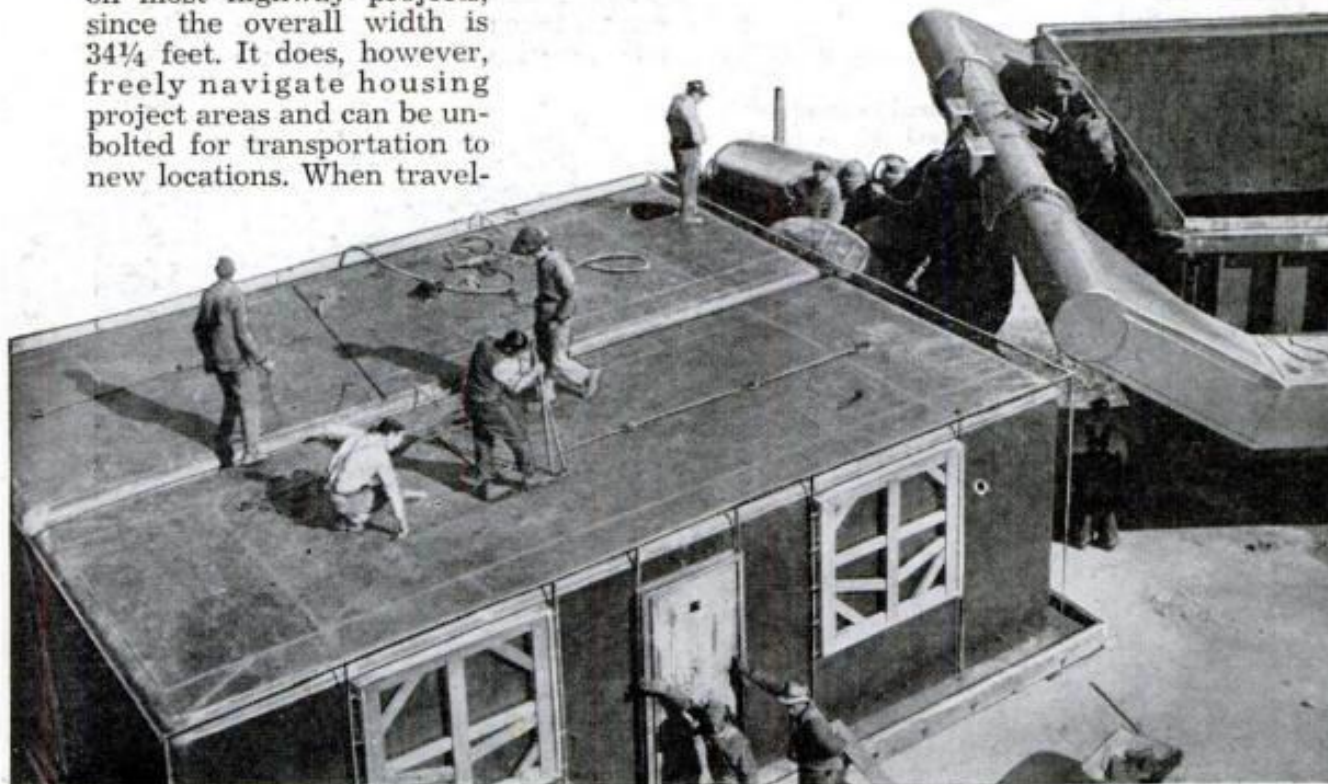
HUGE bombers that have laid "eggs" all over Germany and Japan now have a rival in a mammoth bulldozer-type machine that may some day "lay" houses all over America. It is the latest of many developments by R. G. LeTourneau, Inc., in the house-building field. It really isn't house building, but "house pouring," because this behemoth takes the flowing stream of cement and sets it into a complete house form.

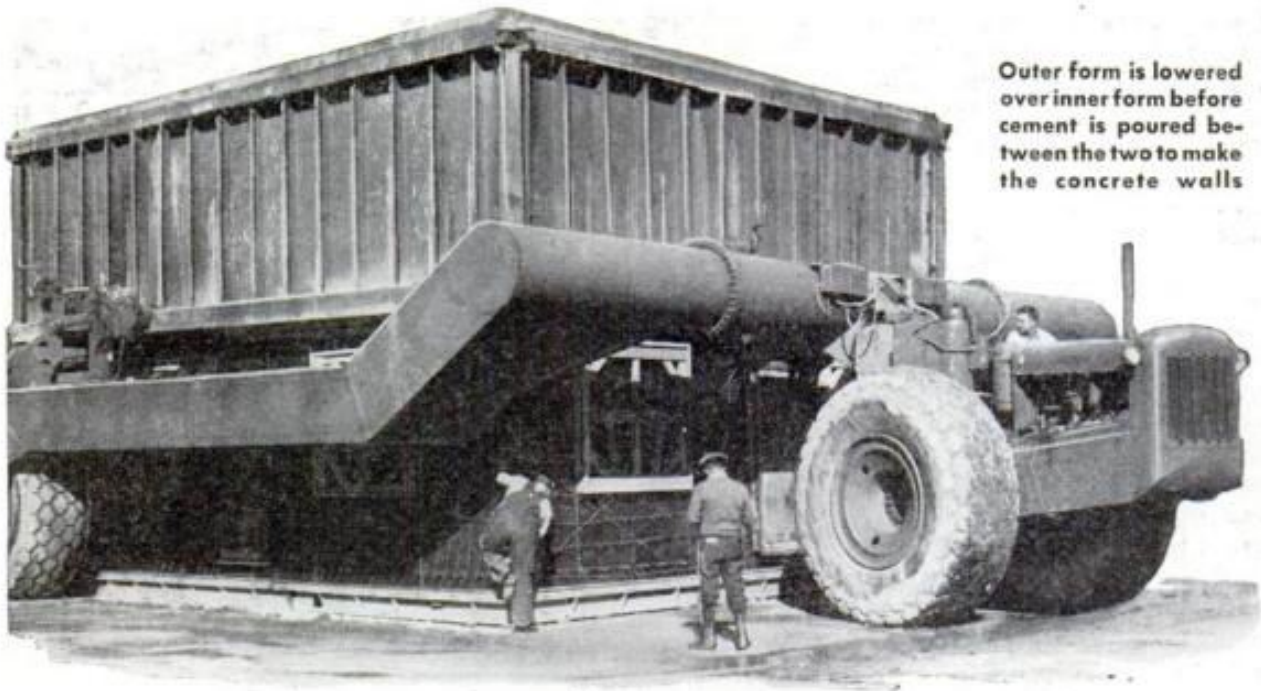
The revolutionary Tournalaid house is far beyond the blueprint stage. Several already have been constructed and are in use near Vicksburg, Miss. The need for housing the families of LeTourneau employees and for factory offices gave birth to the mammoth Tournalayer. Dimensions of the bowl of the vehicle are 24 by 30 by 9.5 feet—the earthmoving capacity of such a box would be 317 cubic yards, or 21 big scraper loads.

That is only for comparison, because it is not designed for earthmoving and is too wide for maneuvering on most highway projects, since the overall width is 34¼ feet. It does, however, freely navigate housing project areas and can be unbolted for transportation to new locations. When travel-



Laid in a day, the concrete home and its floor plan (above). Inner form (below) provides "nest" over which Tournalayer drops its load





Outer form is lowered over inner form before cement is poured between the two to make the concrete walls

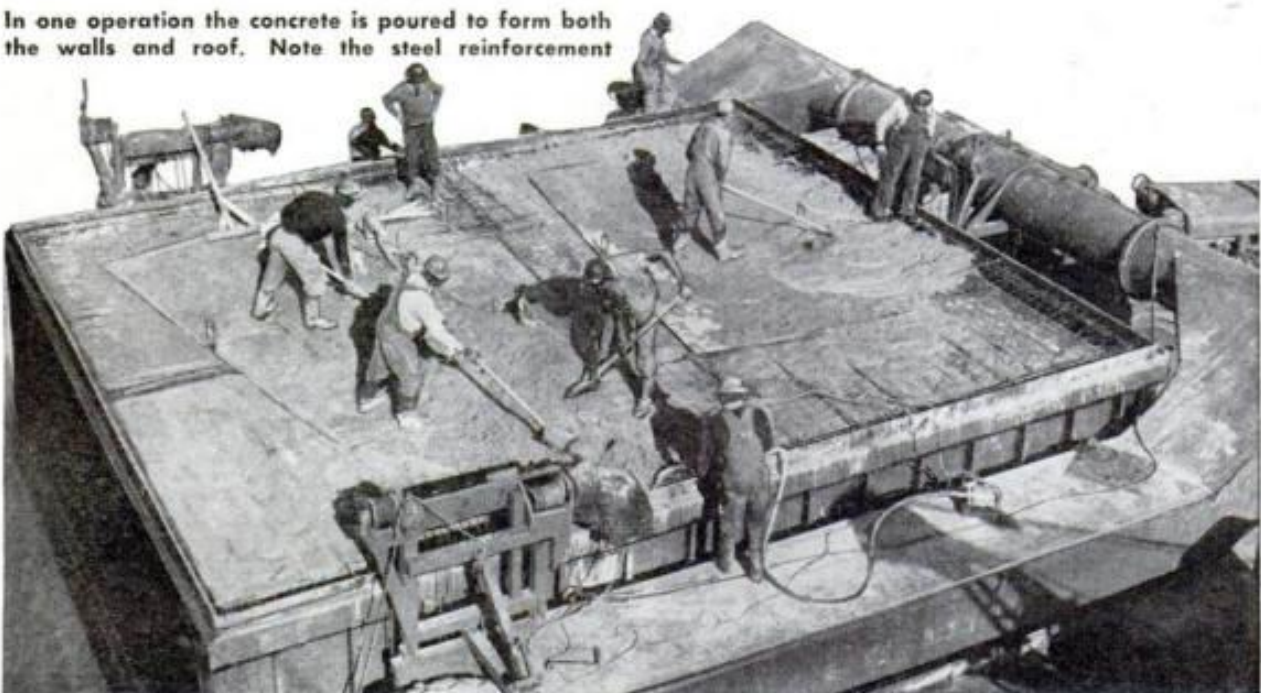
ing, this strange contraption has no bottom. After the concrete from a huge mixer has been poured within its form and has set, the Tournalayer transports it to the new site. After the exact spot for the new home has been determined, the operator presses a button and the bowl slowly lifts to disclose a rectangular concrete house, with doors, windows and partitions.

The Tournalaid house form is in three sections—one outside. The inside form is composed of two independent sections so spaced that a partition wall can be poured between them.

After the two inside forms have been covered with reinforcing mesh, the Tournalayer straddles them and lowers over them the outside form, which is the body

or bowl of the Tournalayer. The concrete is poured. After it has had time to set, the operator collapses the inside form walls away from the house by pressing an electric button. He presses another button and the outside form with the house is lifted up. Lowering its load to traveling level, the Tournalayer walks off to the house site. There it brings the form down to the ground, lays its egg, lifts the form off and struts back. The house is left standing on a broad foundation which is part of its walls. In the meantime the inside forms have been expanded by reversing the action on their walls and are ready for covering with reinforcing mesh. The operator or foreman takes a look at his print for the next structure, then spots doors and win-

In one operation the concrete is poured to form both the walls and roof. Note the steel reinforcement



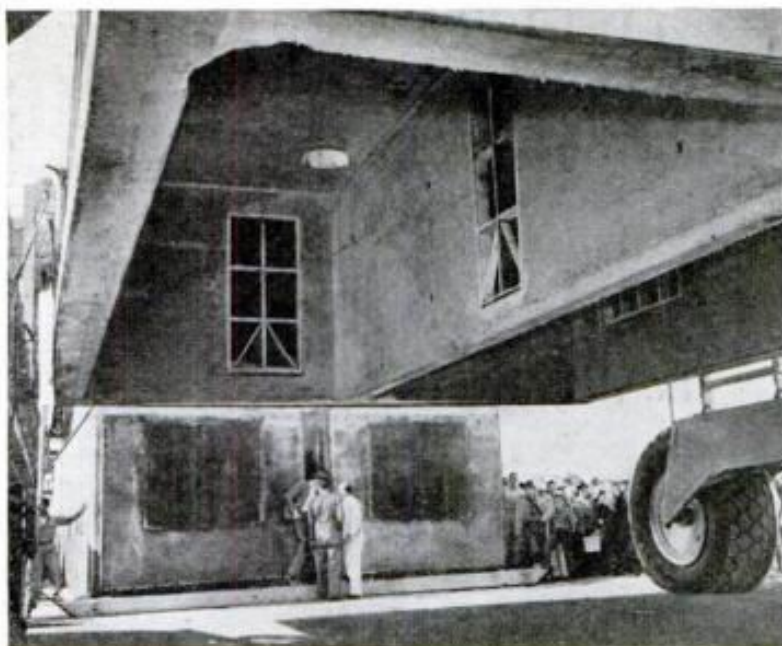
dows wherever they are required by pegging metal frames into the holes which are conveniently located all over the walls of the form.

All this work of the automatic house builder, however, takes place after a certain amount of hand work. The first step is to lay a concrete floor with quick-drying cement. Contractors may lay long rows of floors, opening the way for quick setting of entire blocks of homes. Floor-laying is done in the usual manner and does not require any help from the Tournalayer. All utility lead-ins are laid with the floor, as well as a system of hot water pipes which run through the floor to provide radiant heating.

Tourna-transit-mixers—which are in R. G. LeTourneau's mind, although not yet on the drawing boards—equipped with extra high dumping facilities, can bring concrete from the batch plant and pour 30 cubic yards of concrete—about five loads—at a cost of about \$10 a yard in place. When the house is poured and the concrete is sufficiently set for lifting it off the inside form and traveling, the Tournalayer will waddle off with it to the homesite.

The first LeTourneau prefabricated concrete houses were of a sort of intersecting tunnel design, which the designer referred to as cloverleaf, but most of the factory force called igloo. Curved walls presented problems. Appearance, to speak moderately, was a bit unusual. The Tournalaid house, however, is conventional in shape and with the form or forms now used can be poured in a wide variety of styles and for a multitude of floor plans.

While there are no immediate plans for marketing Tournalaid houses—undoubtedly there will be considerable further development before any such plans will be made—the Vicksburg, Miss., plant and its employees are going to get more Tournalaid homes, offices and factory buildings.



Hardened concrete house is removed from the inner core by hydraulic lifts of the home builder. The home then is deposited on its site

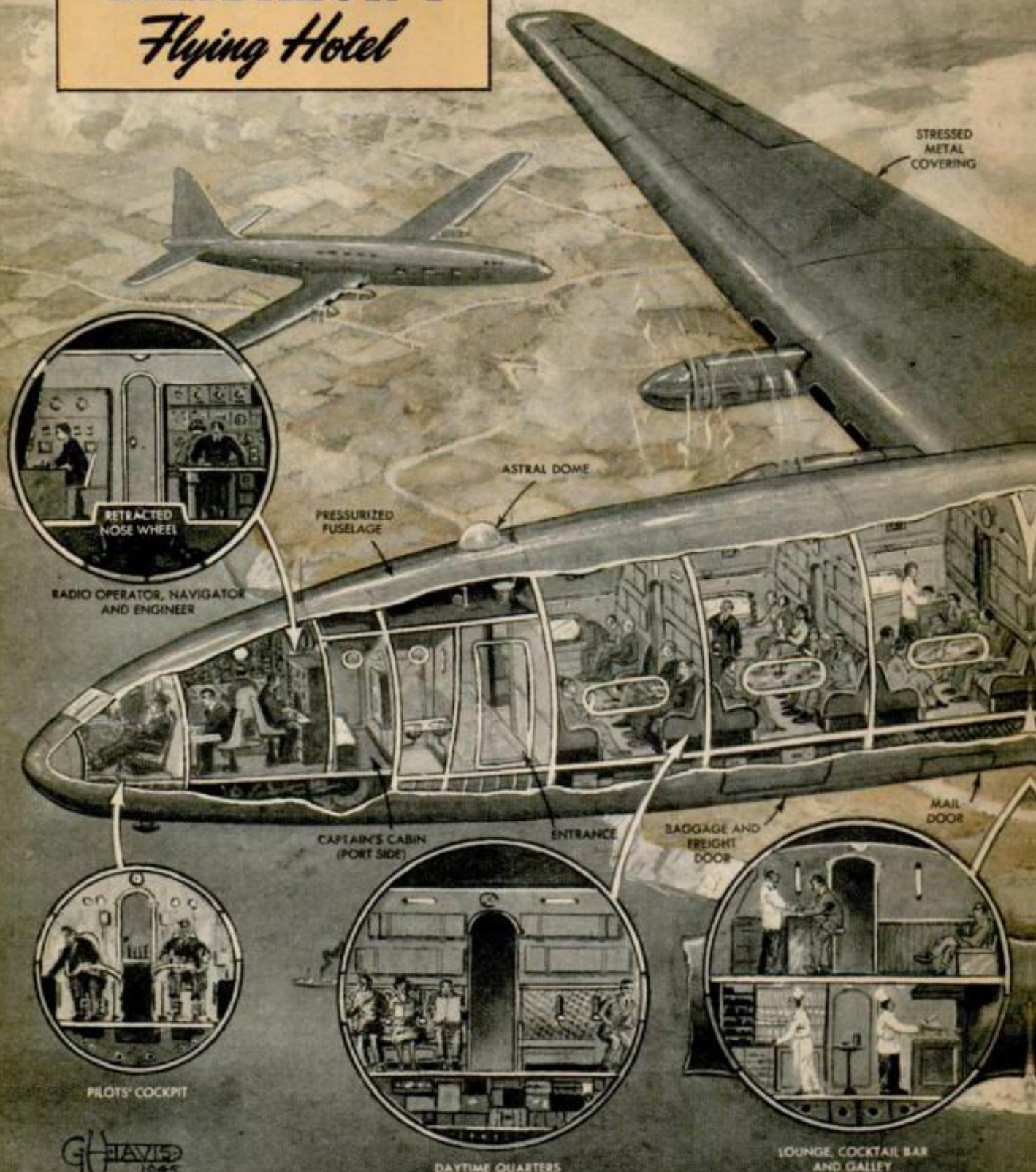


At the site (above) the home is set down and the house layer prepares to move away for more concrete to build another structure. Below, Tournalayer containing another new house is on way to site

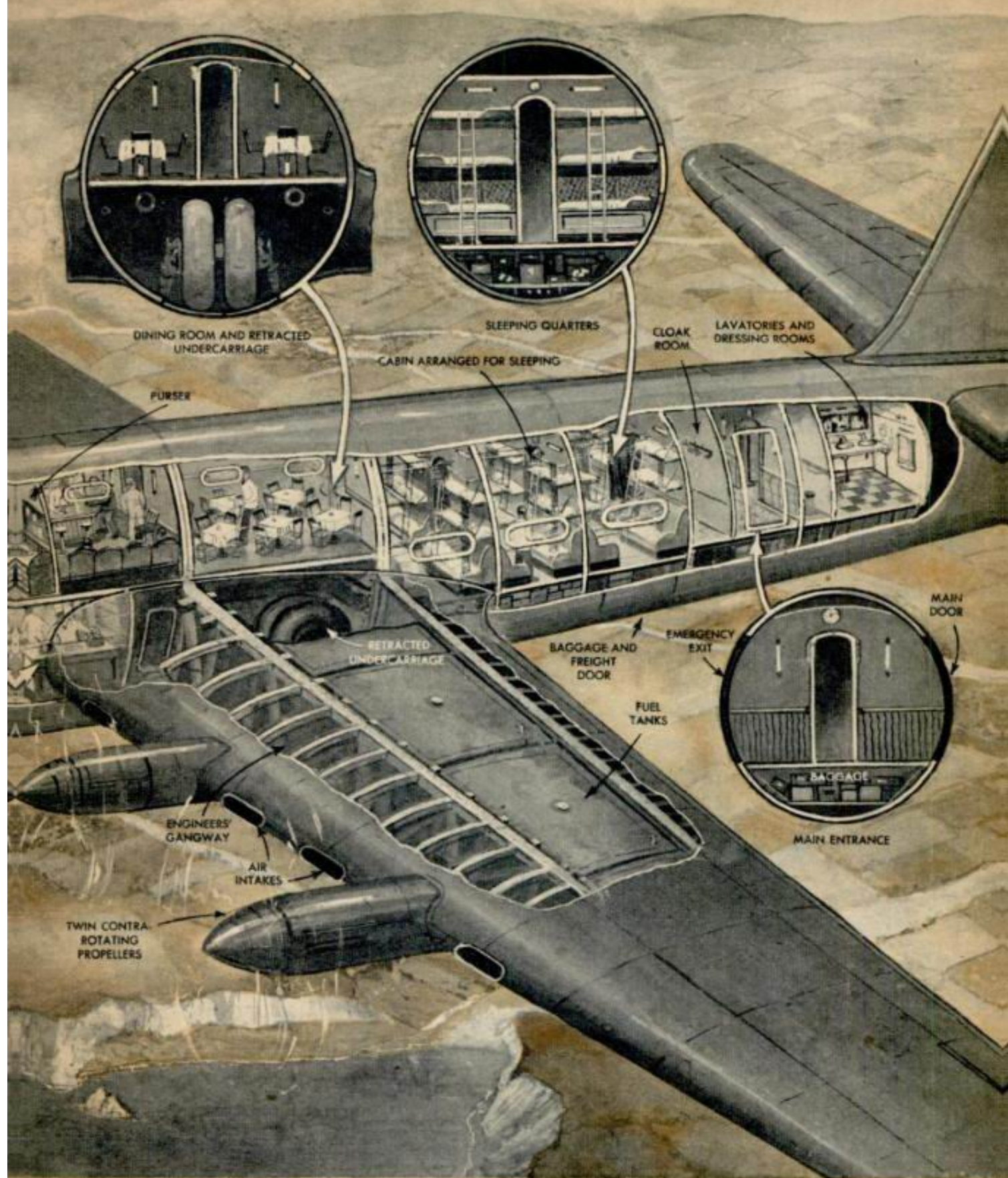


"BRABAZON 1"

Flying Hotel

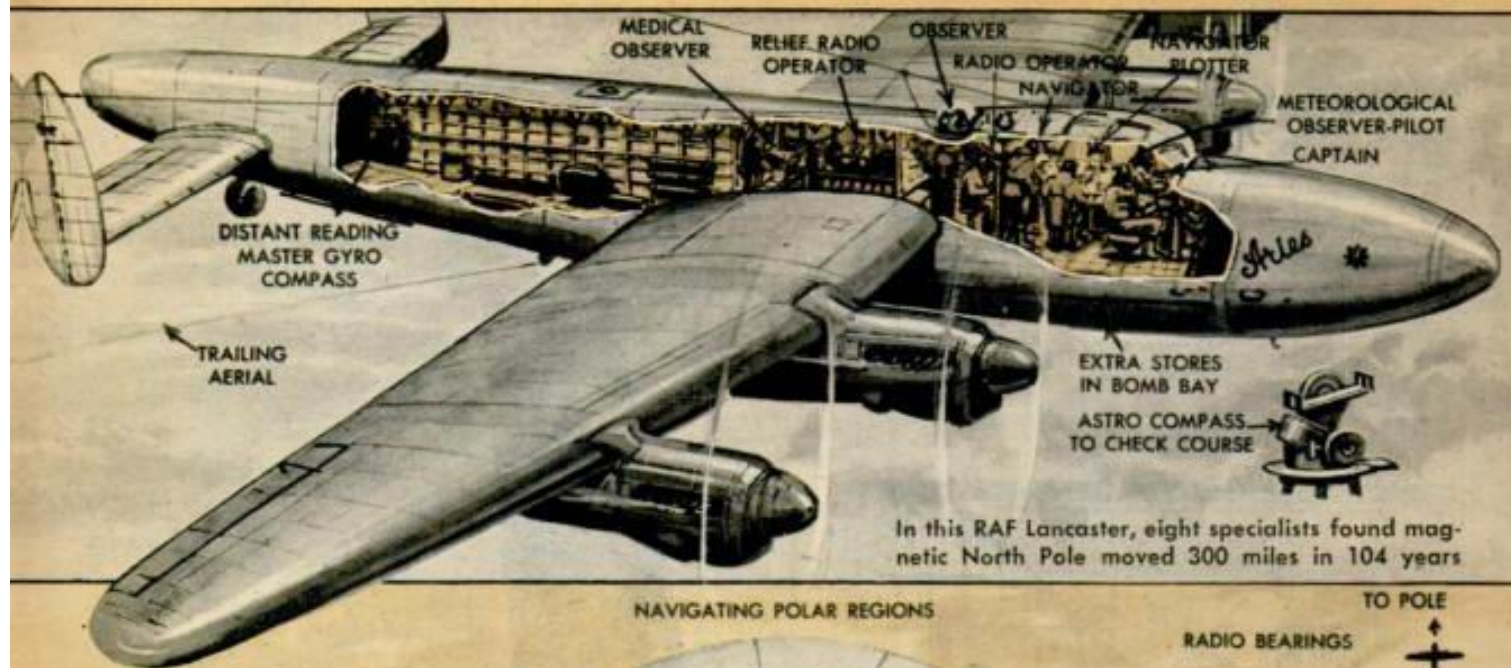


Nearing completion at Bristol, England, is a plywood mockup of Great Britain's largest airliner, the 110-ton Brabazon 1. Although its dimensions have not been officially announced, the wing span is reported to be approximately 270 feet and the overall length nearly 160 feet. It is estimated that the four 2500-horsepower engines, with contrarotating propellers, will give the plane a range of 5000 miles at a 250-mile-an-hour cruising speed. Flights between Australia and England in 48 hours are expected for the plane. One hundred and thirty feet of the fuselage's length will be pressurized. A short-haul version of the Brabazon, named after



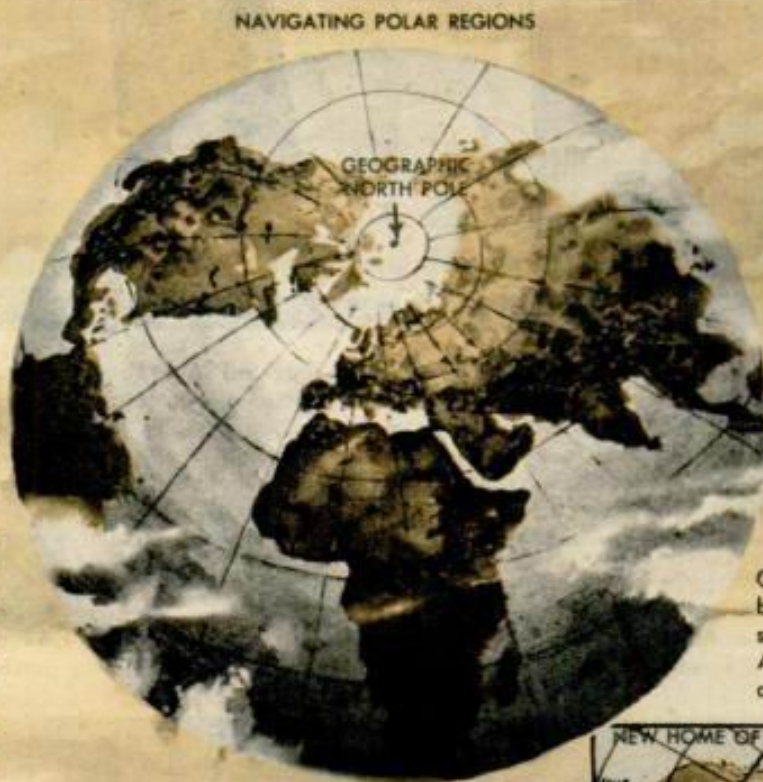
a pioneer English airman, Lord Brabazon, will carry 224 passengers. The long distance type illustrated above will sleep 72. There will be two main passenger salons, separated by a full-height double-deck section housing a cocktail and snack bar, lounge and dining room above and a galley, purser's office and part of the auxiliary gear below. Each main salon will be divided into three compartments, with seats accommodating three passengers facing forward and three to the rear on either side of the aisle. A triple-decker berth arrangement will take care of each compartment's 12 daytime occupants at night. The plane is expected to be ready in 1947

Wandering Magnetic Pole Is Plotted by Plane

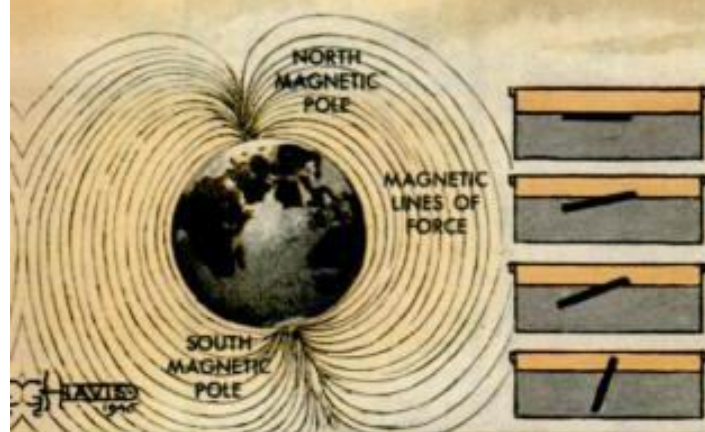


In this RAF Lancaster, eight specialists found magnetic North Pole moved 300 miles in 104 years

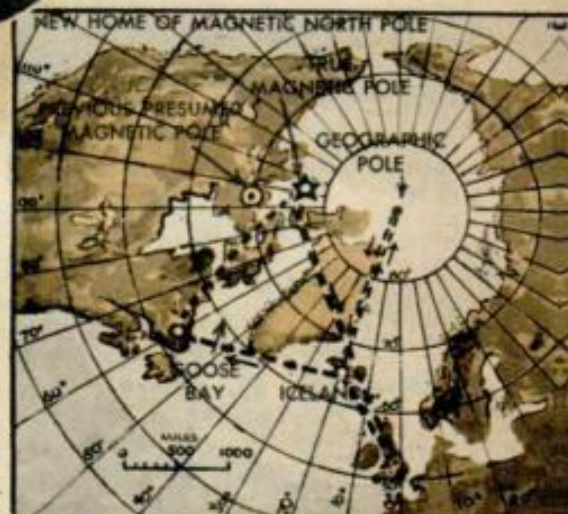
Lines of force below are caused by earth's magnetism, are never parallel with surface except at equator. Aircraft go by geographic pole on map, but compass points to magnetic pole. Courses must allow for variation



On flight, Aries used radio bearings. By strength of signals over aerial, course A was corrected to true course for North Pole, B



Top left, compass needle near equator. Next, dipping toward nearer pole. Then dip increases as magnetic pole is neared. Last, dip near pole of approximately 90 degrees. At that angle in final stage, compass is useless for navigation work



Arrows on map, above right, trace flight of Aries in locating true position of magnetic North Pole. Plane flew from Britain to Iceland, then over geographical North Pole. Flight over Magnetic Pole followed course to Goose Bay. Polar flights of Aries totaled 17,720 miles. Craft carried 7 compasses, 18 special devices

AROUND THE WORLD IN 30 MINUTES ...

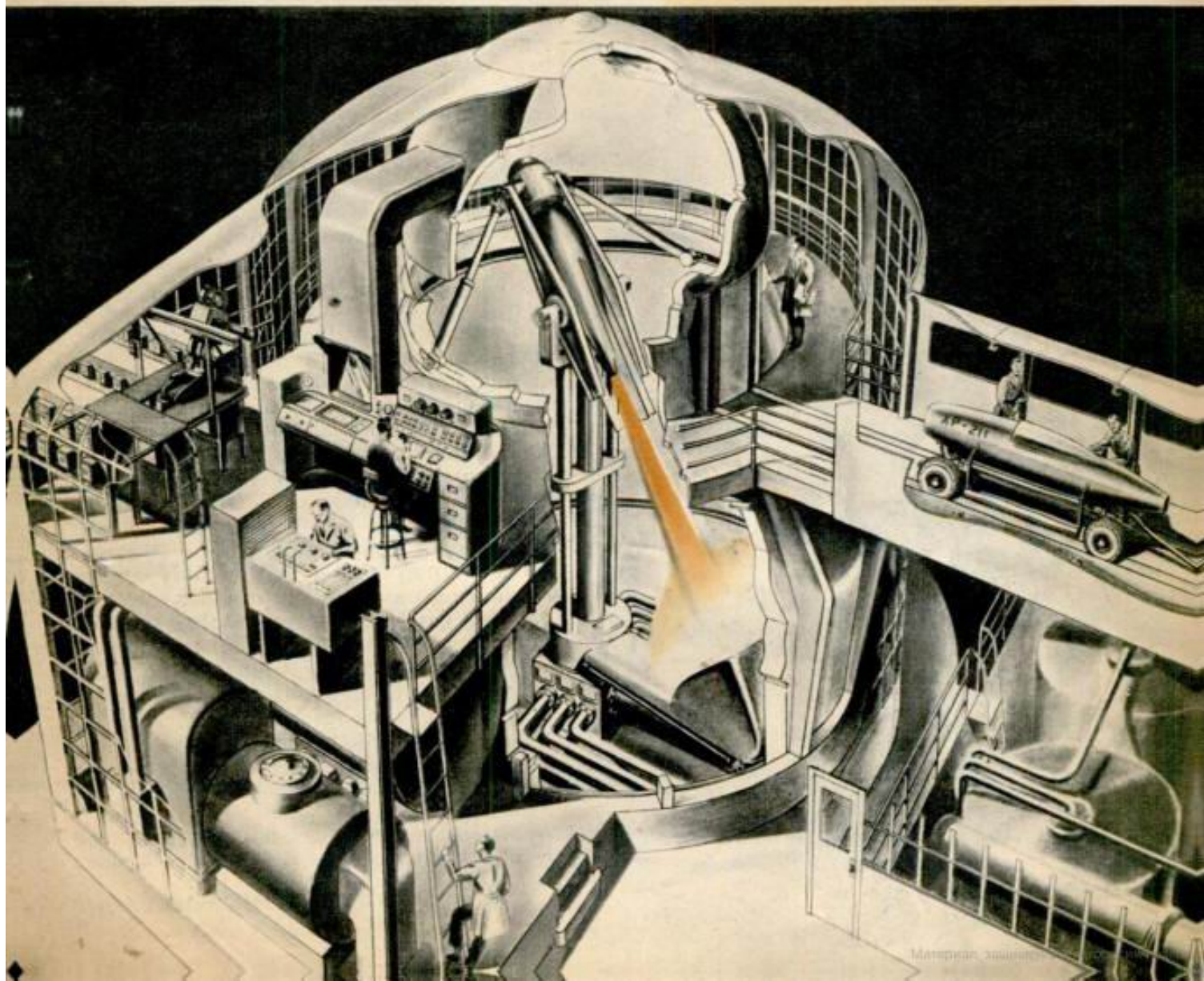
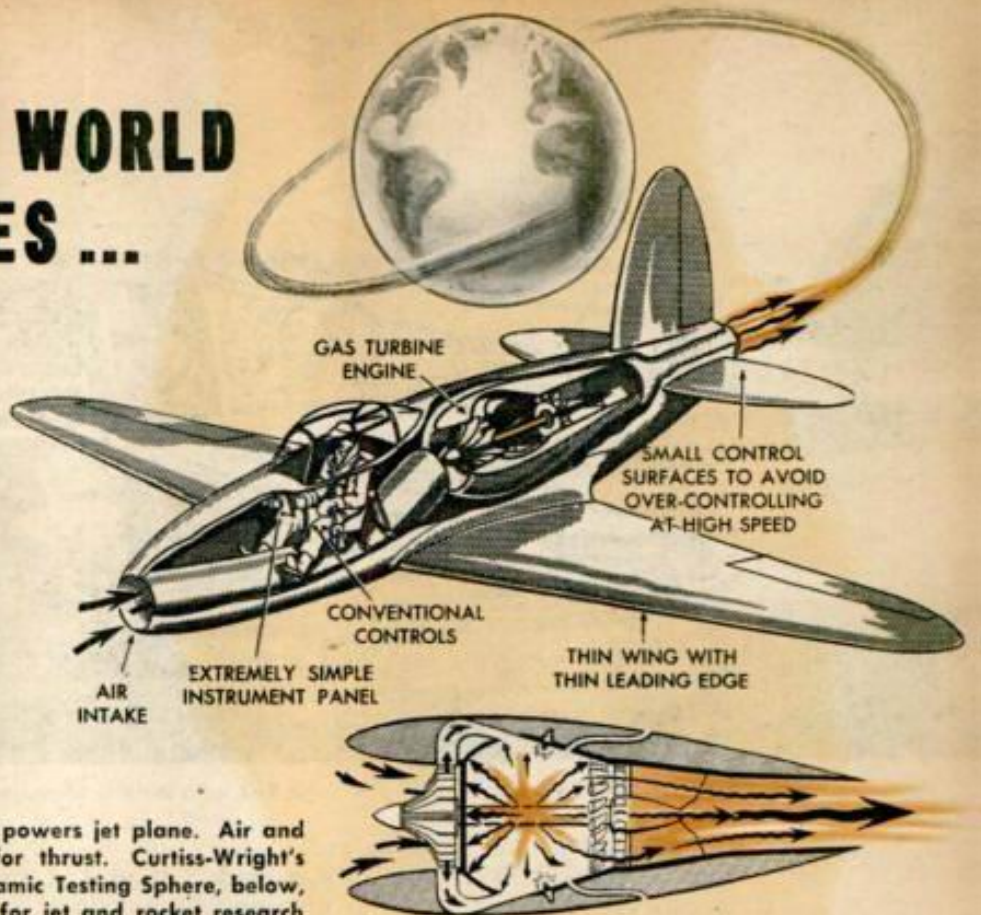
By
Thomas E. Stimson, Jr.

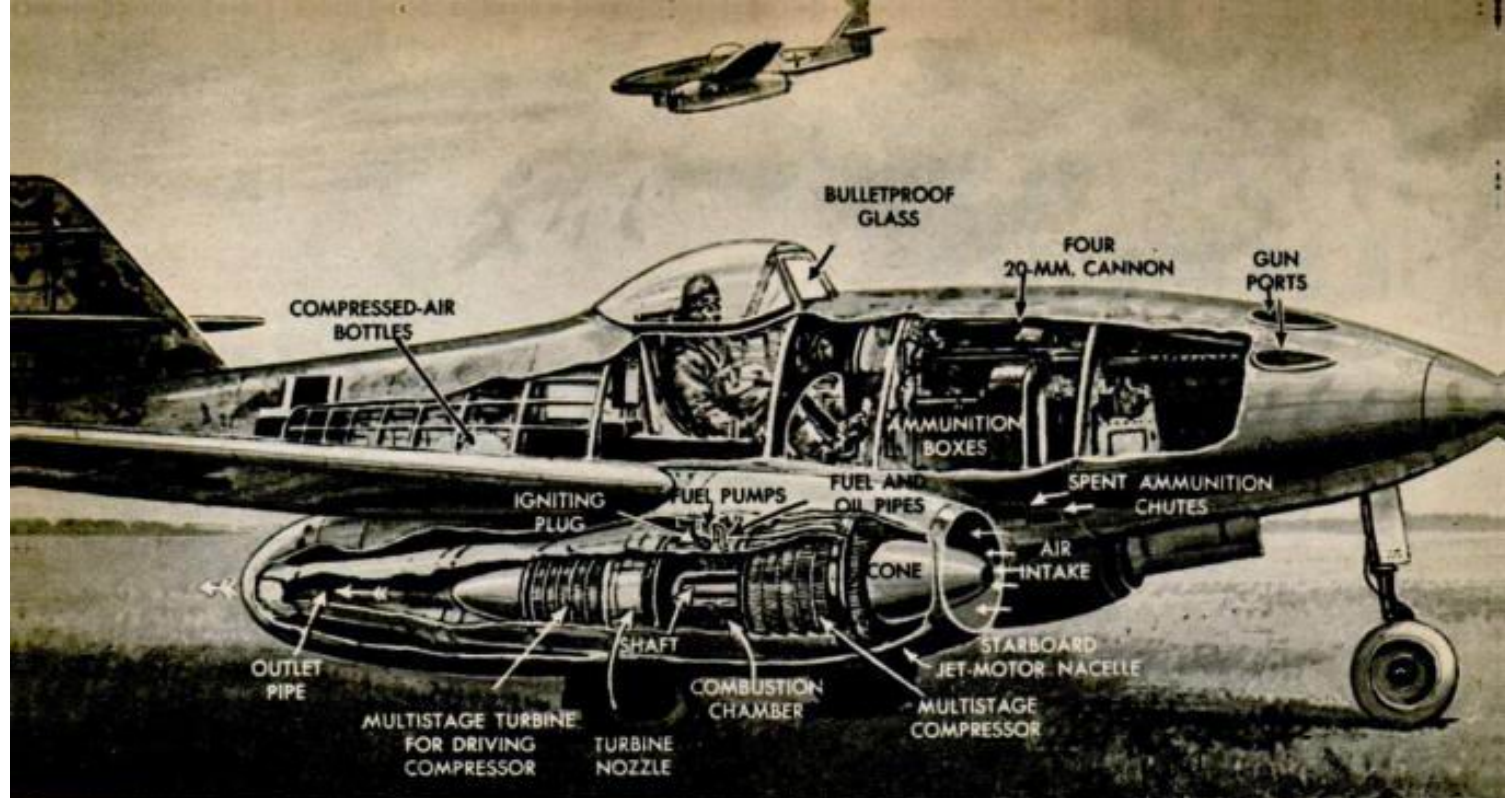
AVIATION designers are looking forward to creating within the "visible future" a rocket ship that would fly at the rate of 100,000 miles per hour.

At least, states Hall Hibbard, vice-president and chief engineer of Lockheed Aircraft Corporation, the basic principles of such a space ship are understood

Gas turbine engine like that at right powers jet plane. Air and fuel ignite in combustion chamber for thrust. Curtiss-Wright's Peter Rossman conceived the Aerodynamic Testing Sphere, below, and Tethered Flight Tunnel, page 35, for jet and rocket research

Drawing courtesy of Industrial Aviation





This is the German twin-engined jet plane ME-262 with details of major parts. It attained 500 to 600 m.p.h.

and the problems that remain are minor in comparison to the ones already solved.

It is conceivable that such an airplane, moving outside the atmosphere, could fly all the way around the world in half an hour. Provided that it could carry enough fuel and a livable atmosphere for its occu-

pants, it could travel to the moon, around it and return to earth between daybreak and dark.

The swiftest vehicle in the world today is our P-80 Shooting Star, Lockheed's jet propulsion aircraft that gets its thrust from a gas turbine. It is a transitional type between the aircraft that get their power from reciprocating engines and the rocket craft of the future.

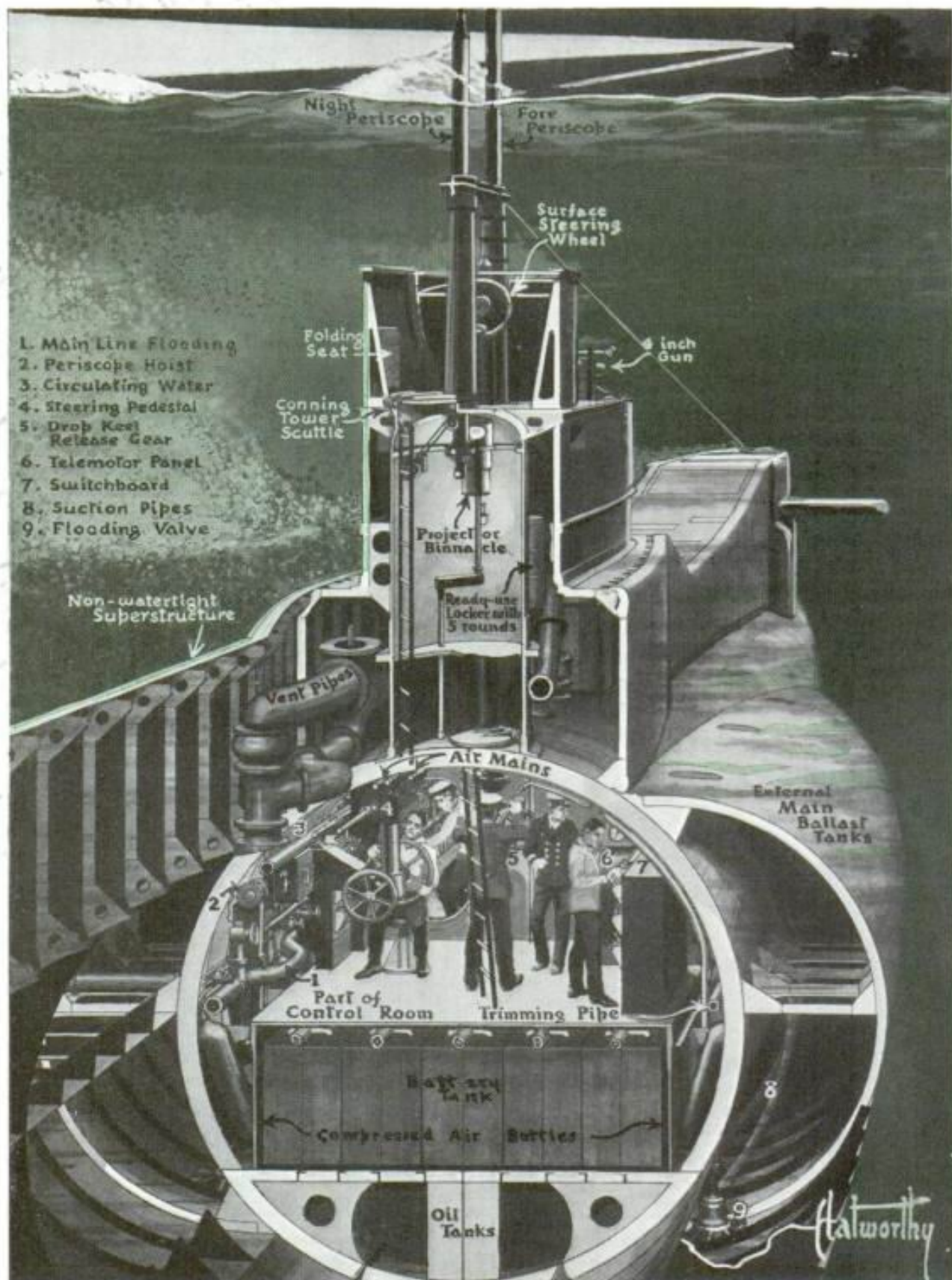
The P-80 wing has a knife-like leading edge and other aerodynamic innovations that master the problems encountered when the speed of sound is approached or surpassed. The pressurized cabin is unique among production fighters.

Small and light, the Shooting Star is extremely maneuverable through use of a hydraulic aileron boost and electrically operated flaps, and can carry heavy loads of ammunition, photographic equipment, bombs and fuel. Ceiling of the P-80 is well above that of propeller driven airplanes. The engine can be completely replaced in 15 minutes. There is no engine torque or vibration. The General Electric jet engine (gas turbine) is installed in the fuselage between the cockpit and tail.

Our atmosphere is both handy and a handicap for aviation. It provides the oxygen that gas turbines and gasoline engines must have to burn their fuel and it also supports the airplane itself. At the same time it contains an arbitrary speed barrier at about 750 miles per hour and an absolute speed limit at about 1500 miles per hour. Beyond that a human being would be burned to a crisp.

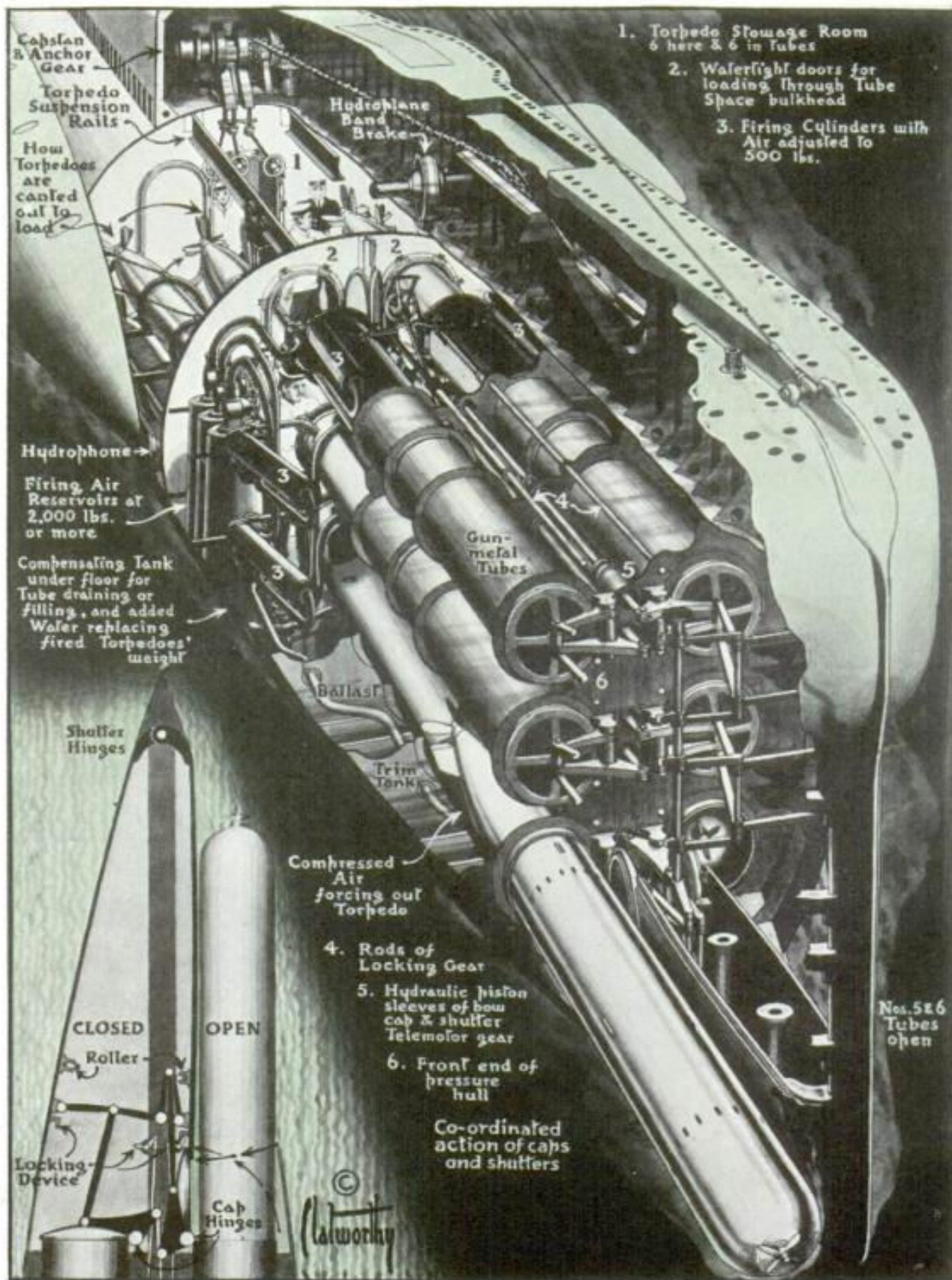
Jet flyer inflates "G" suit. This will inflate itself automatically in fast dives and stop pilot blackouts





© S. W. Clatworthy

Cross-section drawing of British submarine shows the deadly craft submerged, its two periscopes just breaking the surface and leaving their telltale wake. Below is the projector binnacle and still further below the control room with battery tanks beneath. Bulges on sides are main external ballast tanks. Atop the conning tower is a wheel for steering while navigating on surface, and just forward is the four-inch gun used in surface fighting. The gun is used in preference to torpedoes whenever possible



© S. W. Clatworthy

This drawing reveals the essential mechanism for discharging a torpedo from a submarine. The deadly weapon, which travels forty to sixty miles an hour after being launched, is not fired from the ship by explosive but by compressed air which forces it from tube. The actual moment of firing is controlled from periscope amidships where tubes are aimed by maneuvering the whole boat. The inset at left shows the coordinated action of the bow caps and shutters as seen from above. This ship carries twelve torpedoes

The **HORNETS** of the **AIR CORPS**

POPULAR MECHANICS

MACHINE



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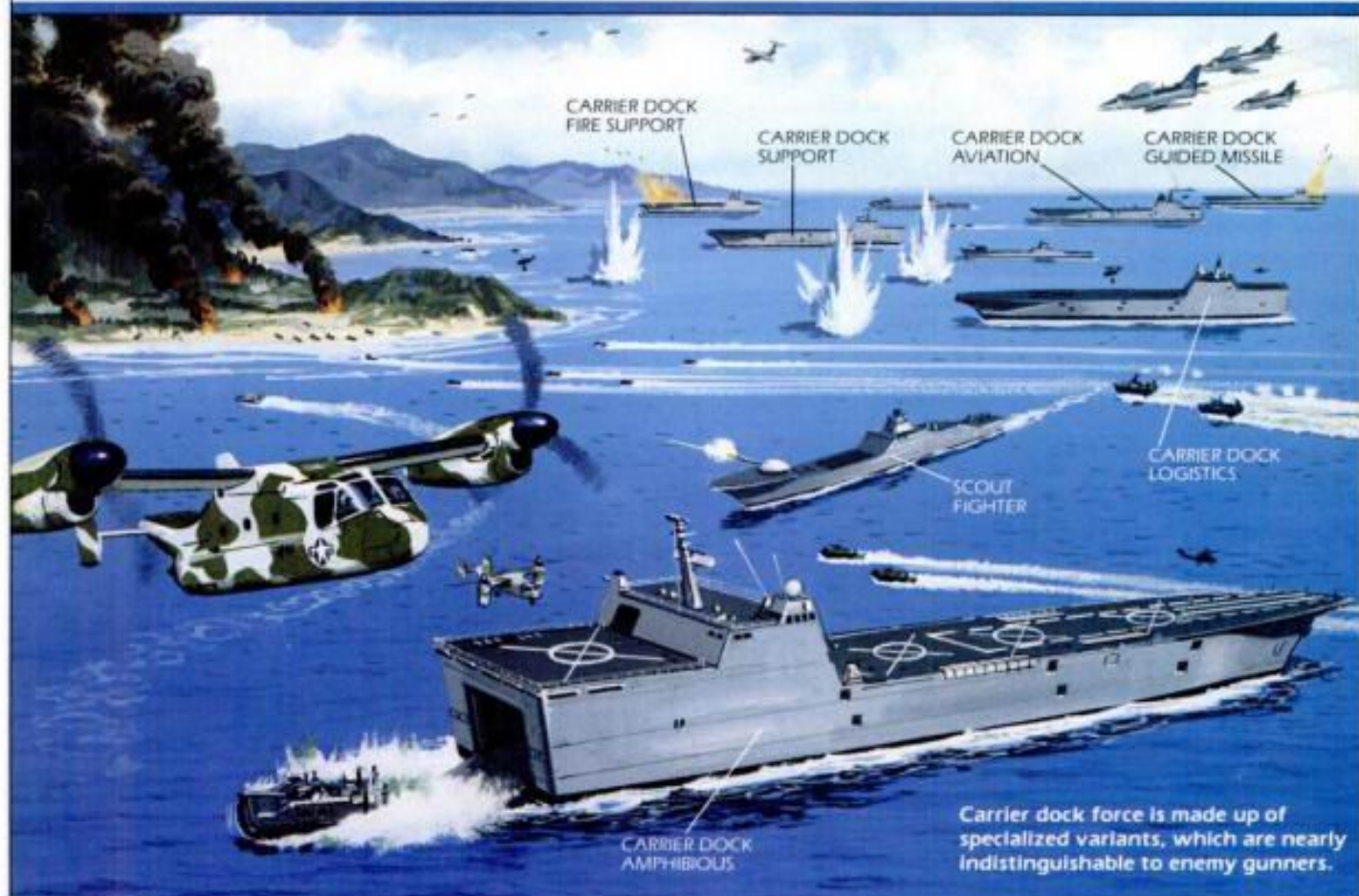
MARCH
25 CENTS

SEE PAGE 347



TECH UPDATE

News Of Tomorrow's Technology Today



Carrier dock force is made up of specialized variants, which are nearly indistinguishable to enemy gunners.

Battleforce 2030: One Design, Many Missions

BETHESDA, MD—Forty years from now, the Navy may build its battle groups the same way Chrysler builds cars—with a diverse range of special-purpose vessels, all based on a single platform.

Researchers at the Navy's David Taylor Research Center envision a type of vessel called the Carrier Dock Multimission. Although each ship of the type could be customized for amphibious operations, logistics, fire support or other tasks, all variants would share a landing deck for short- and vertical-take-off aircraft, a well deck to release amphibious assault craft, and common combat and propulsion systems.

The advantages? In addition to reduced costs due to economies of scale, the ships' similar silhouettes would conceal their mission-specific roles from the enemy. And if a key ship is disabled, another can quickly be adapted to pinch hit for it.

The V-22 tilt-rotor figures heavily into the concept, as does an AEGIS-type anti-air warfare system, in which vessels cooperate in launching and targeting missiles. Gas turbine generators would provide electric propulsion and could feed power to directed-energy weapons and aircraft catapults.

Editor: Abe Dane
Assistant Editor: Greg Pope
Contributor: Oliver Fultz

Carrier dock ships would travel with conventional nuclear-powered carriers and a new class of minidestroyers

called scout fighters. Proponents hope the vessels can be phased in, starting around the year 2000.

Highlights This Month

- **Riding The Iron Highway**—Rail haulers pin hopes on ultralong freight car.
- **Electric Firepower**—High-watt weaponry for tomorrow's tanks.
- **Magnets Map The Mind**—Superconductors detail the brain's electric landscape.
- **Rush For Slush**—Semifrozen hydrogen could fuel and cool aerospace planes.
- **Sneaky Sea Drones**—Unmanned vehicles augment naval power.
- **Steel Gets Lean And Mean**—New technology strips costs from steelmaking.

TECH UPDATE

News Of Tomorrow's Technology Today

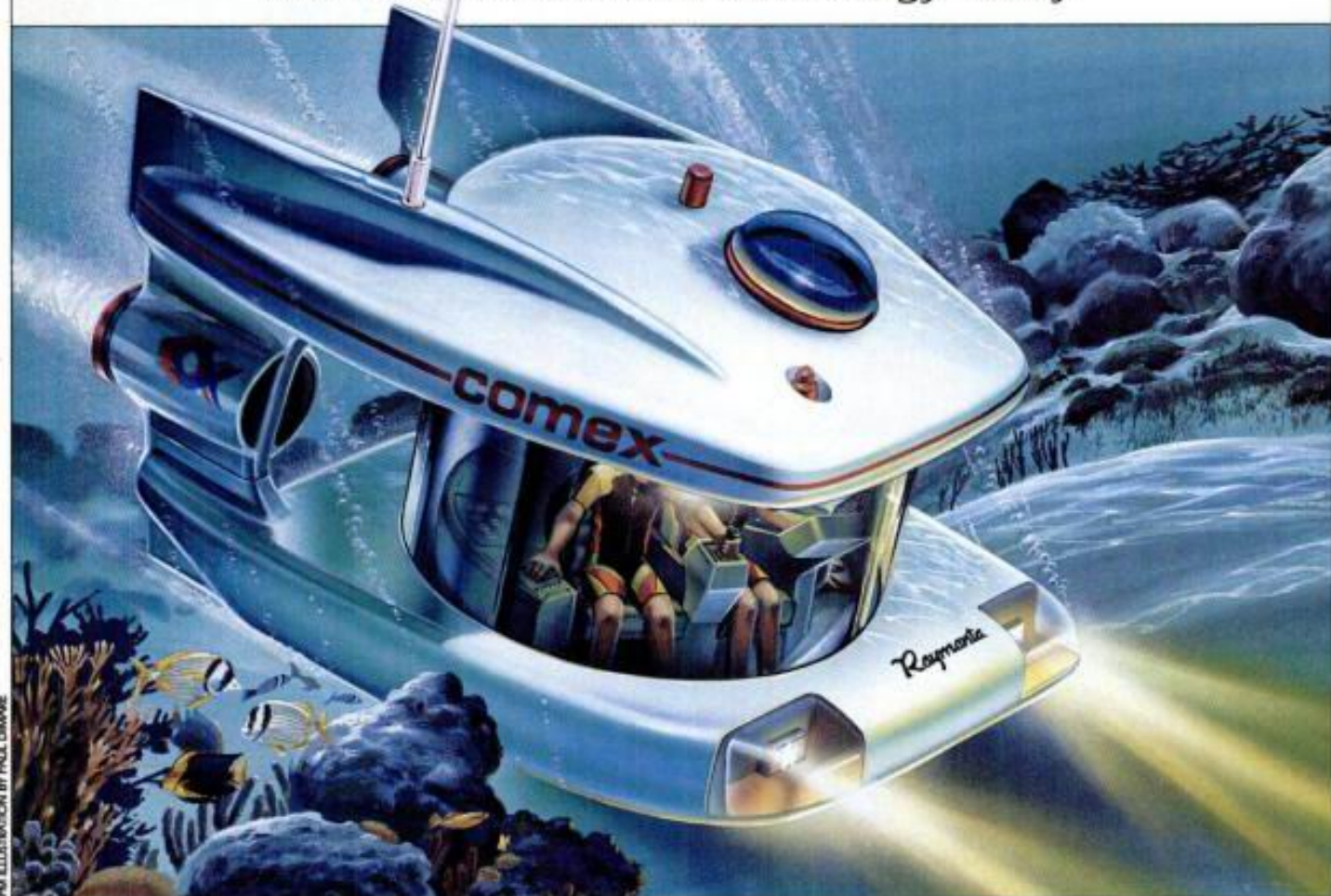


ILLUSTRATION BY PAUL DUNN

Personal Viewmobile Of The Deep

MARSEILLES, FRANCE—Submersibles with clear plastic hulls have the potential to revolutionize underwater leisure. So far, however, only the French outfit Comex Marine Parks has put one in regular operation—the Seabus, currently diving off the coast of Monte Carlo. Now Comex is scaling down the same acrylic-hull technology to give small groups and well-heeled individuals deep-sea views.

The Raymanta 6 vaguely suggests a bulbous, aquatic Honda Civic—although at \$1 million, it's hardly an economy vehicle.

Beyond its acrylic hull, the little submersible has

an unusual upper fairing. Small underwater vehicles are typically topped with a flanged deck that provides at least 30 in. of freeboard to allow disembarking in choppy waters. But the Raymanta's slim upper surface is sculpted for hydrodynamics.

That means Raymanta must dock with a dedicated mothership or pontoon to load and unload passengers. If seas are too rough, a rubber buoyancy tube will inflate around the hull to pop the sub's top 3 ft. above the waves.

Comex will fit the sub

with the usual safety measures required for classification by the American Bureau of Shipping.

With clear, 8½-ft.-dia. pressure hull, streamlined Raymanta 6 scoots to 200-ft. depths on twin 2½-hp thrusters.

Highlights This Month

■ **Wind Tunnels Of Your Mind**—Virtual-reality aerodynamics.

■ **Ground-Up Chopper**—New copter is first clean-sheet design in a decade.

■ **Incredible Shrinking Dome**—Telescope building telescopes itself.

■ **Ballistic Birdshot**—Hyperspeed weapons carry shotgun warheads.

■ **Hail To The Caddy**—President Clinton's White House wheels.

■ **Ready AIM Fired**—AIM-120A AMRAAM missile makes its debut.

Editor: Abe Dane
Assistant Editor: Greg Pope
Contributors: Philip Chien, Mike Fillon

IRRESISTIBLE FORCE

the few publications to place a representative aboard America's low-level penetrator (see "Fail Safe '88," page 54, Jan. '88). And on our recent ride on a low-level B-52 mission through America's heartland we observed the simulated release of air-launched cruise missiles, a new role for the mighty Stratofortress. Our interviews, technical briefings and flight time have given us a comprehensive understanding of where SAC is headed. B-52s and B-1Bs already stand alert. But significant hurdles must be overcome before the B-52, B-1B and B-2 can coalesce into an interdependent force of devastating destructive potential—a potential that, ironically, may be the key to a lasting peace.

A look back

While the Northrop B-2 Stealth bomber was capturing headlines, keeping the B-52 flying and fighting despite its increasingly geriatric airframe was the preoccupation of flight crews at scattered SAC bases.

Improved East Bloc surface-to-air missiles and the B-52's immense radar cross section have turned America's oldest bomber (it was first manufac-

tured by Boeing in 1952) into a superb delivery vehicle for air-launched cruise missiles. These weapons upgrades in the face of a significantly greater threat have transformed the B-52 into a logical platform for eliminating certain targets—particularly early-warning sensing devices—at standoff ranges.

But the Strategic Air Command is also formulating plans to turn part of the B-52 fleet into a low-level attack bomber in a conventional scenario. SAC planners foresee the need for deep interdiction of enemy troops and supplies in time of theater conflict. Upgrades in night-vision and terrain-avoidance gear will allow conventionally armed B-52s to fly to long-range targets in any weather. Just a handful of bases around the world—from Diego Garcia in the Indian Ocean to Keflavik in Iceland—gives the B-52 virtually global coverage.

The B-52's offensive avionics have been upgraded, and the ALQ-172 electronic countermeasures system has proven successful. Other conventional warfighting equipment include the GPS global positioning system for precision navigation (soon to become

fully operational), an infrared night vision system and head-up display (a highly unusual technology transfer from the fighter community) and an offensive avionics system (OAS). Similar to ground-attack systems found in F-16s and F/A-18s, the B-52's OAS senses altitude, barometric pressure, inertial navigation plot and other factors, evaluates target data, and adjusts the plane's inbound course and weapons release.

Equipped with Harpoon antiship missiles and mines, the B-52 can easily convert to sea patrol plane, adhering to a concept SAC planners call MASS, or Maritime Air Sea Surveillance. MASS calls for protection of shipping lanes in the event of an East Bloc attack on Western Europe.

Fast forward

While the future of the B-52—assisted by avionics upgrades and careful airframe monitoring for signs of stress—has never appeared brighter, it's been anything but smooth sailing for the Rockwell B-1B. Failure of the Eaton Corp. ALQ-161 electronic countermeasures system to perform according to manufacturer's claims



TOMORROW'S SAC BOMBER MISSION

In a greatly condensed artist's view of the future strategic battle space, B-52s lead a strike using air-launched cruise missiles to knock out enemy sensing platforms and airfields. B-1Bs firing short-range attack missiles and dropping gravity bombs strike fixed missile silos and SAM sites. The B-2 penetrates heavier defenses to eliminate hardened or mobile missile sites.

has been a lightning rod for criticism of the \$275 million swing-wing bomber. Crashes due to bird strikes and pilot error haven't helped the B-1B's reputation, nor have pesky but persistent anomalies like fuel leaks.

But the world's first low-level strategic penetrator has earned high praise from air crews, who fly the B-1B through the world's roughest terrain. "Fighting" the B-1B is tough physical and mental work, as I discovered on that training flight out of Dyess Air Force Base in Abilene, Texas. It takes some pretty aggressive flying to execute terrain-masking tactics through densely wooded mountain passes. The low-level rationale becomes immediately clear when you're clearing ridge lines by 100 ft. at 550 knots. While chaff, flares, radar location and warning systems and terrain-following radar give the B-1B some potent (though still not perfect) capabilities, its real strength is this ability to fly low at high subsonic speeds, often within the crags and chasms of the topography, to foil enemy detection methods. Indeed, the smaller, faster, more agile B-1B carries greater payload than the B-52

and drops it with greater accuracy.

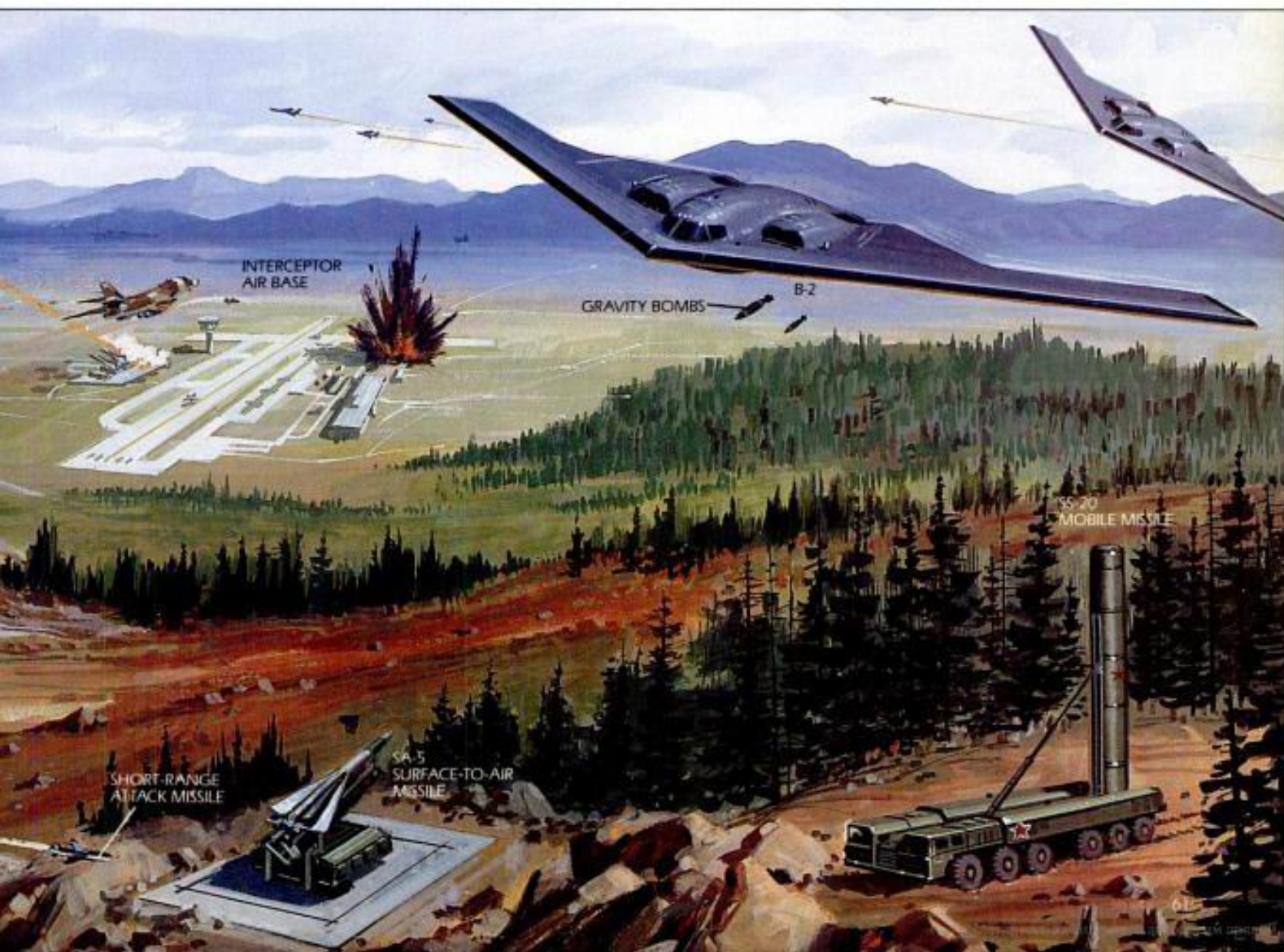
Despite its shortcomings, SAC must depend on the B-1B more and more as time passes, not only as a means of penetrating Soviet air space with gravity bombs, but as a standoff platform for advanced cruise missiles as the Soviet threat evolves. The B-1B also has on its side one very sobering and incontrovertible fact. The B-2 is several years from full production, if it ever passes Congressional budget scrutiny, making the decision to buy the B-1B all the more astute.

The new technology

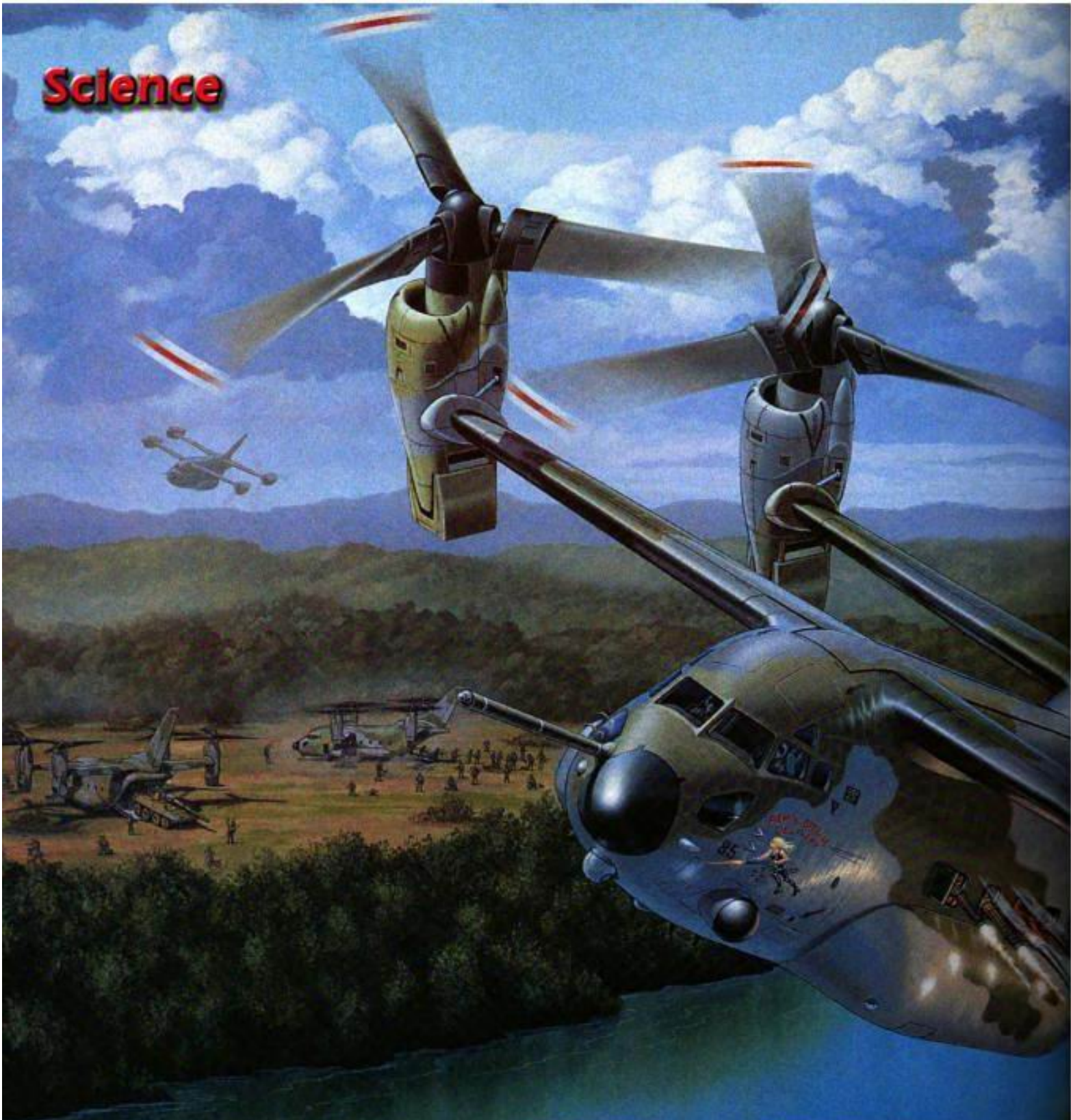
As with any expensive, complex weapons system, the B-2 is hardly without criticism. Detractors charge that the latest generation of ground, spaced-based and bistatic radars, not to mention advanced optical and infrared sensors, will detect the B-2 as it penetrates Soviet air space to strike hardened or mobile targets. They say that billions in stealth technology can not protect B-2 from easy interception once detected, and that standoff cruise missiles will perform the mission more accurately at less risk. They also point out that the B-2 mis-

sion of finding and eliminating relocatable ICBM launchers depends too heavily on satellite reconnaissance, which will be eliminated in the first phase of a general nuclear exchange. General Bernard P. Randolph, commander of Air Force Systems Command which is developing the B-2, forcefully disagrees, ticking off B-2's advantages. A 6000-mile unrefueled range and an effective 50,000 pound internal weapons load of short-range attack missiles, nuclear gravity bombs or conventional ordnance give B-2 a formidable punch in a variety of mission scenarios. B-2s flying from just four bases—two in the states and two overseas—could cover most of the world's hot-spots with just one refueling.

The B-2's flying-wing platform, first proposed by Jack Northrop for the YB-49 back in the late 40s, is thought by the Air Force to embody the proper combination of load carrying, flight efficiency and low observability. If a B-1B has a radar cross-section $\frac{1}{100}$ th that of a B-52, the radar cross-section of a B-2 is said to be $\frac{1}{10}$ th that of a B-1B—giving the B-2 the appearance of a bird on an enemy



Science



V-44

The Pentagon's next transport flies like a plane, lands like a helicopter and unloads enough firepower to start—or stop—a war.

BY SCOTT R. GOURLEY, Illustration by Mark McCandlish

► Some planes are so

beautiful they could hang in art museums even if they couldn't fly. Others—the Wart Hog tank-killer comes to mind—are as homely as their names. And then

COVER STORY

there is the Pentagon's next wonder-plane, the V-44. It's ugly, coyote ugly, with wings. Four wings to be exact. Each is tipped with a tilting nacelle that converts the V-44 from a helicopter that can land or take off wherever a truck can make a U-turn to a 300-mph fixed-wing transport, troop carrier or gunship. Still on the drawing board, the

plane we've informally designated the V-44 derives from the V-22 Osprey, a two-wing tiltrotor that is now undergoing final evaluations by the Marine Corps. The need for a quad-rotor version stems from what defense analysts predict will be fundamental changes in the nature of war in the 21st century. Desert Storm was your father's war. Tomorrow, low-intensity conflicts will be the rule as the anointed battle the infidels, plant police take on drug barons, and taxmen shoot it out with money launderers.

Uncle Sam has decided to step into the fray as the policeman of this new world disorder. His billy club will be a new military deployment strategy that puts ready-



"The FTR concept can be traced back to the 1960s when the Curtiss-Wright Corp. built the X-19."



to-fight brigades on the ground in 96 hours. American armed forces will get into the action on a new type of plane, the V-44 Future Transport Rotorcraft (FTR).

Twice A V-22

The FTR will provide a capability that does not exist anywhere in the world today—and perhaps will replace the helicopter for military operations. The concept for the aerial assault platform comes from Bell Helicopter Textron. Having teamed with Boeing on the twin-engine V-22 Osprey tiltrotor program, Bell has developed the concept for a larger fuselage. Envisioned to be about the size of a stretched C-130 Hercules, the FTR would feature two V-22-type wings, each having an engine and a combination rotor-propeller mounted at the outboard tips. The exact configuration has yet to be determined. Some versions show a tailless aircraft, others have an airframe more along the lines of a C-130.

There is no disagreement about the interior. The V-44 is designed to be a heavy hauler. "Imagine this aircraft with a cabin large enough to internally carry an 8 x 8 x 40-ft. container, several helicopters, all types of high mobility multipurpose wheeled vehicles, light armored vehicles, eight standard loading pallets, or 70 [medivac] litters," reads an industry analysis describing the concept. "Imagine an aircraft that could transport 80 to 100 troops or 10 to 20 tons of equipment and supplies at speeds greater than 300 mph over distances from 1000 to 2000 miles and

A quad tiltrotor could be put into production as early as 2010.



then safely land vertically, without the need for runways or airports."

The FTR concept can be traced back as far as the early 1960s when the Curtiss-Wright Corp. built the X-19, a small quad-rotor testbed. After 50 successful test flights, it was destroyed in an accident. A second X-19 was scrapped. Enthusiasm for the FTR, however, is based on the technical success of the V-22 Osprey. These aircraft can be configured to carry 24 combat troops or up to 20,000 pounds of internal or external cargo at twice the speed

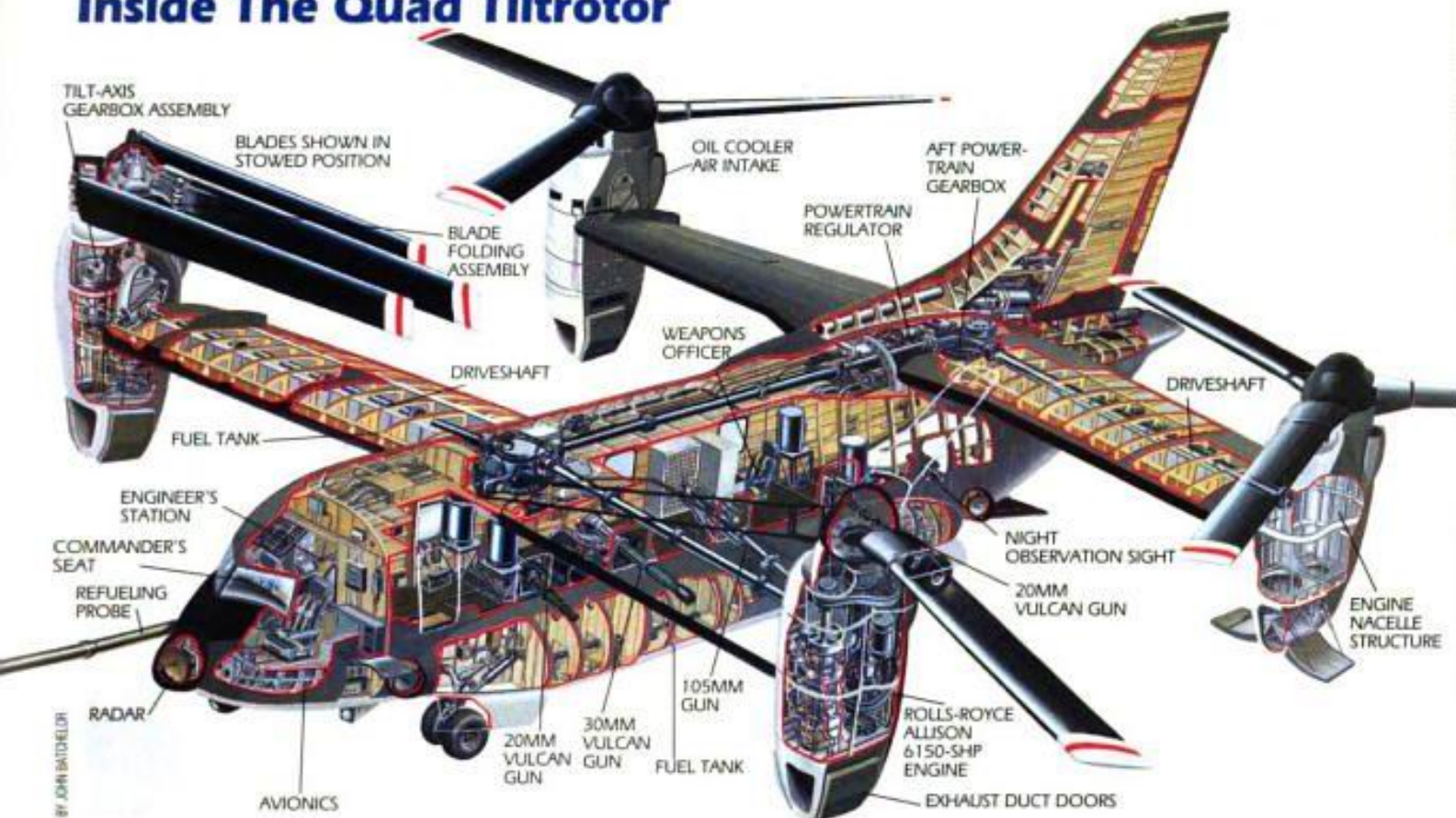
of a helicopter. U.S. procurement plans call for 360 Marine Corps MV-22 aircraft and 50 U.S. Air Force CV-22 aircraft. Using parts common with the Marine MV-22, the Air Force CV-22 modification includes the addition of internal-wing fuel tanks and terrain-avoidance and terrain-following radars. It also has been given an enhanced electronic warfare suite, additional cockpit seating for a flight engineer, an aerial refueling probe and an internally mounted rescue hoist.

The FTR will use a pair of V-22 propulsion systems. Each is based on two Rolls-Royce Allison AE 1107C 6150-shp engines and a

computer-controlled rotor coordination system that permits a safe landing if one engine loses power.

An obvious question is whether the four rotors could operate in such close proximity without creating turbulence that would shake apart the aircraft or make it impossible to control. To answer this question, Bell draws on data reaching back to its X-22 ducted propeller quad tiltrotor, which flew 500 flights between 1966 and 1988. The results encouraged Bell to test a pair of V-22s at a distance approximating

Inside The Quad Tiltrotor



the spacing between the fore and aft wings of a V-44. According to Dick Spivey, Bell's director of ad-

operations, support Air Force Aerospace Expeditionary Force units and meet many Army require-

ability to transport 8 to 12 tons of cargo over 600 miles with return at cruise speeds of 300 knots. Bell Helicopter engineers believe that their FTR concept would come very close to meeting these criteria.

A Formidable Gunship

In addition to the FTR's cargo-hauling abilities, the possibility of putting tiltrotor technology into combat can be seen in another industry analysis. With advanced laser weapons and precision fire control, the craft could provide protection for overtaking a captured or damaged airport or sea-port, making such sites accessible to allied forces.

Gunship applications are just one of several ideas being explored. A joint panel is looking at all of the rotorcraft possibilities. "They're looking at joint common lift replacement aircraft, to include a medium assault, a utility and an attack and anti-armor aircraft," explains Marine Corps Capt. Aisha Bakkar-Poe. "The Marine Corps' view is that tiltrotor is the way of the future because it has such a longer range and goes so much faster that it almost makes a helicopter obsolete."



Troop buildups would no longer require runways.

vanced concepts, the test was a success. Water tunnel tests showed that the rotor wakes from the front engines flowed down and inboard—below and inboard of the rear rotors. Technically, there is no reason this bird shouldn't fly.

Thus configured, it could carry twice the payload and eight times the internal volume of cargo transported by the V-22. A true multiservice aircraft, it would reportedly meet the expanded needs of the Marine Corps' Ship-To-Objective Maneuver

ments for a future Joint Transport Rotorcraft (JTR). In the Army's case, officials envision a JTR that will replace some of the aging CH-47 Chinook helicopters. The Navy has its eye on the quad tiltrotor to make deliveries to its ocean-going fleet, much as the C-2A Greyhound now services carriers.

Early requirements issued by the Defense Department call for the

For Science News And Story Updates

Check the Science channel on the PMZone Web site at popularmechanics.com/science



21ST CENTURY FIGHTER

The F-22 air superiority fighter pushes the envelopes of stealth and speed.

BY WILLIAM GARVEY

► They call it Raptor and it truly is the most fearsome bird in the sky. Its mission is to control the highest ground, the airspace above the battle area. It is a simple but effective strategy. The Air Force

COVER STORY boasts that no U.S. ground soldier has been killed by enemy aircraft in more than 40 years, a period that includes the Vietnam War, invasions of Panama and Grenada, and Desert Storm.

Keeping hostile skies all-American has been the job of some noteworthy fighters, including the F-100 Super Sabre and F-4 Phantom. For the past 20 years the U.S. Air Force's alpha wolf has been the twin-engine F-15C Eagle air superiority fighter. Although the Eagle is superb at its work—F-15Cs shot down 32 enemy fighters in air-to-air combat during the Gulf War—foreign-

made fighters with equal or superior capabilities are becoming operational, as is a new generation of ultra-lethal, foreign-made missiles. Thus, the possibility exists that the bad guys could eventually outgun us.

"Americans don't have a God-given right to air dominance," says former Air Force Chief of Staff Gen. Ronald Fogleman. "Somebody's got to invest in it."

Proud Heritage

With continued, undisputed mastery of the skies in mind, the Air Force began developing a successor for the then-new F-15 back in the mid-1970s. Studies revealed that to dominate airspace in the 21st century, an aircraft would have to be very fast, agile, well-armed, and although the term was still classified, stealthy.

After considering six separate proposals, in 1986 the Air Force issued development contracts for two fighter



designs, the YF-22 (above) to be built by Lockheed in partnership with Boeing and General Dynamics, and the YF-23 from Northrop teamed with McDonnell Douglas. The service also ordered competing engines from General Electric and Pratt & Whitney.

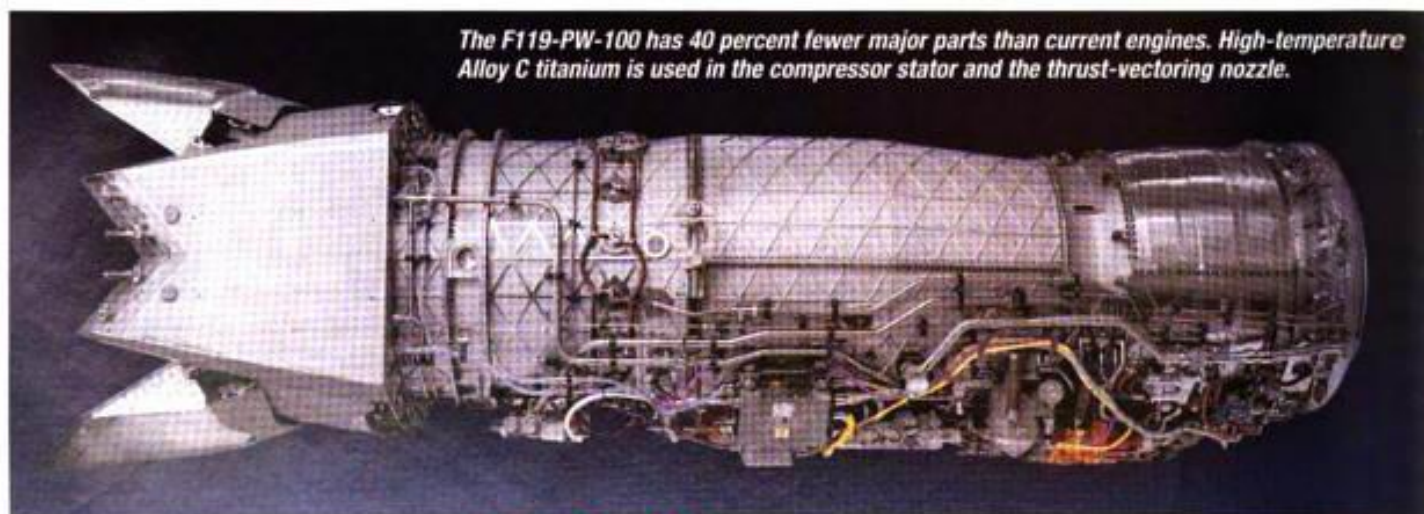
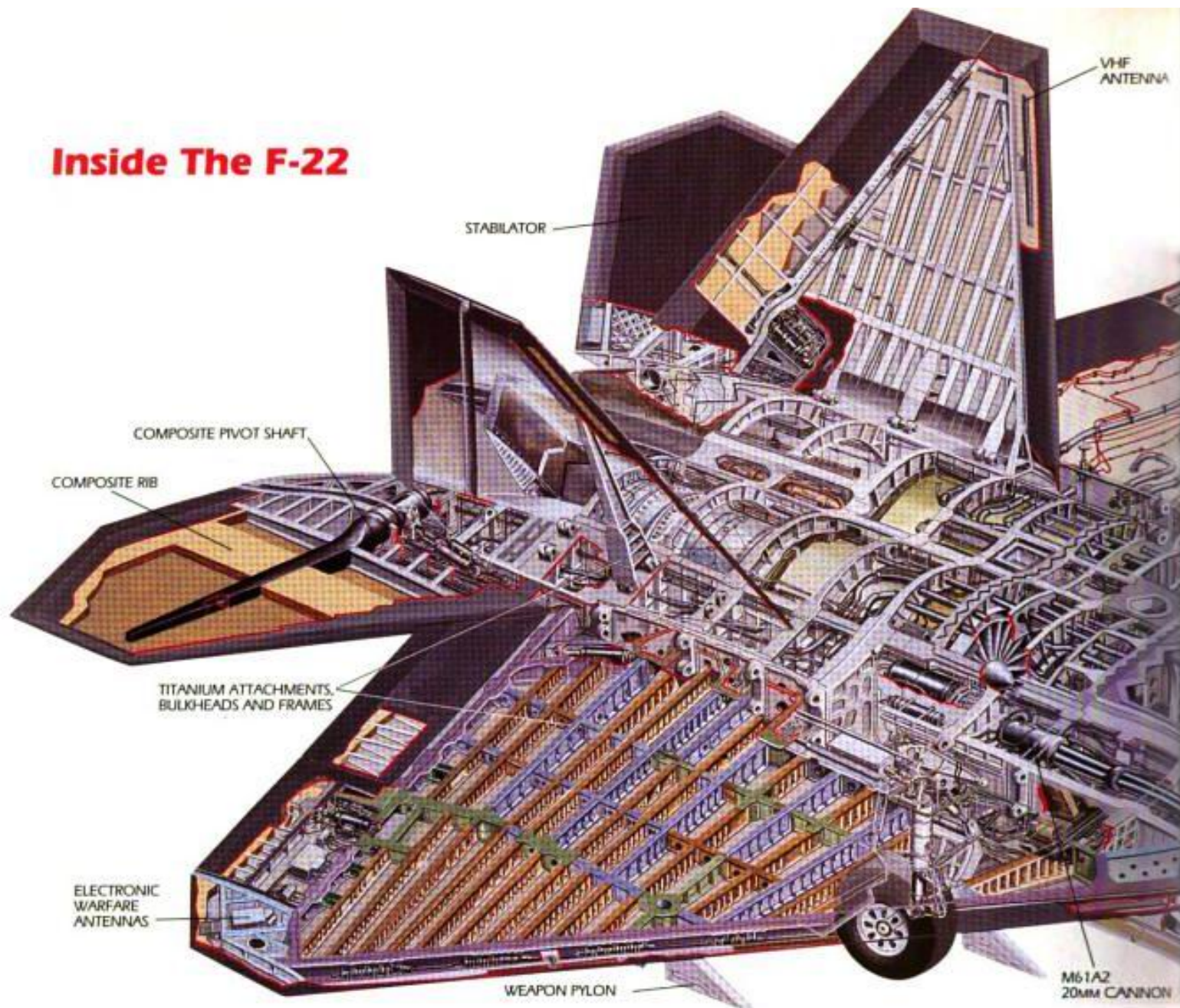
The competition to be chosen to build the service's Advanced Tactical Fighter was intense: The winner would receive contracts for up to 750 aircraft worth tens of billions of dollars. The stakes just don't get any higher. By 1990, the two prototypes were dogfighting for their futures in evaluation flights over Edwards Air Force Base in California. In April of the following year the Air Force selected as its winner the Lockheed/Boeing/General Dynamics design, powered by a pair of Pratt & Whitney F119-PW-100 engines. The YF-22 would become the F-22. It would not only be America's 21st century fighter, it would raise the technological bar

for all high-performance aircraft to follow.

Continued flight and wind-tunnel testing resulted in refinements to the design, and in December 1993 parts fabrication began for the first flying F-22. The division of work had Boeing handling software and avionics integration and building the aft fuselage and wings. Lockheed's Fort Worth division, which it acquired from General Dynamics in 1993, was responsible for the mid-fuselage and armament. And what was then Lockheed-Marietta, and is now Lockheed Martin, was charged with building the forward fuselage, vertical fins and stabilizers, and landing gear, and doing the final assembly.

On April 9, 1997, with flags aflutter, congressmen pontificating, workers cheering and salutes and smiles everywhere, the first true F-22 was unveiled in Lockheed Martin's Georgia assembly plant, while the walls reverberated with the strains of "The Spirit of America."

Inside The F-22



The F119-PW-100 has 40 percent fewer major parts than current engines. High-temperature Alloy C titanium is used in the compressor stator and the thrust-vectoring nozzle.

"This is a great day for America," Fogleman said. "We have no desire to control the world. We have an equally great desire to see that no one else controls the world."

The Raptor's mission is to see that no one does.

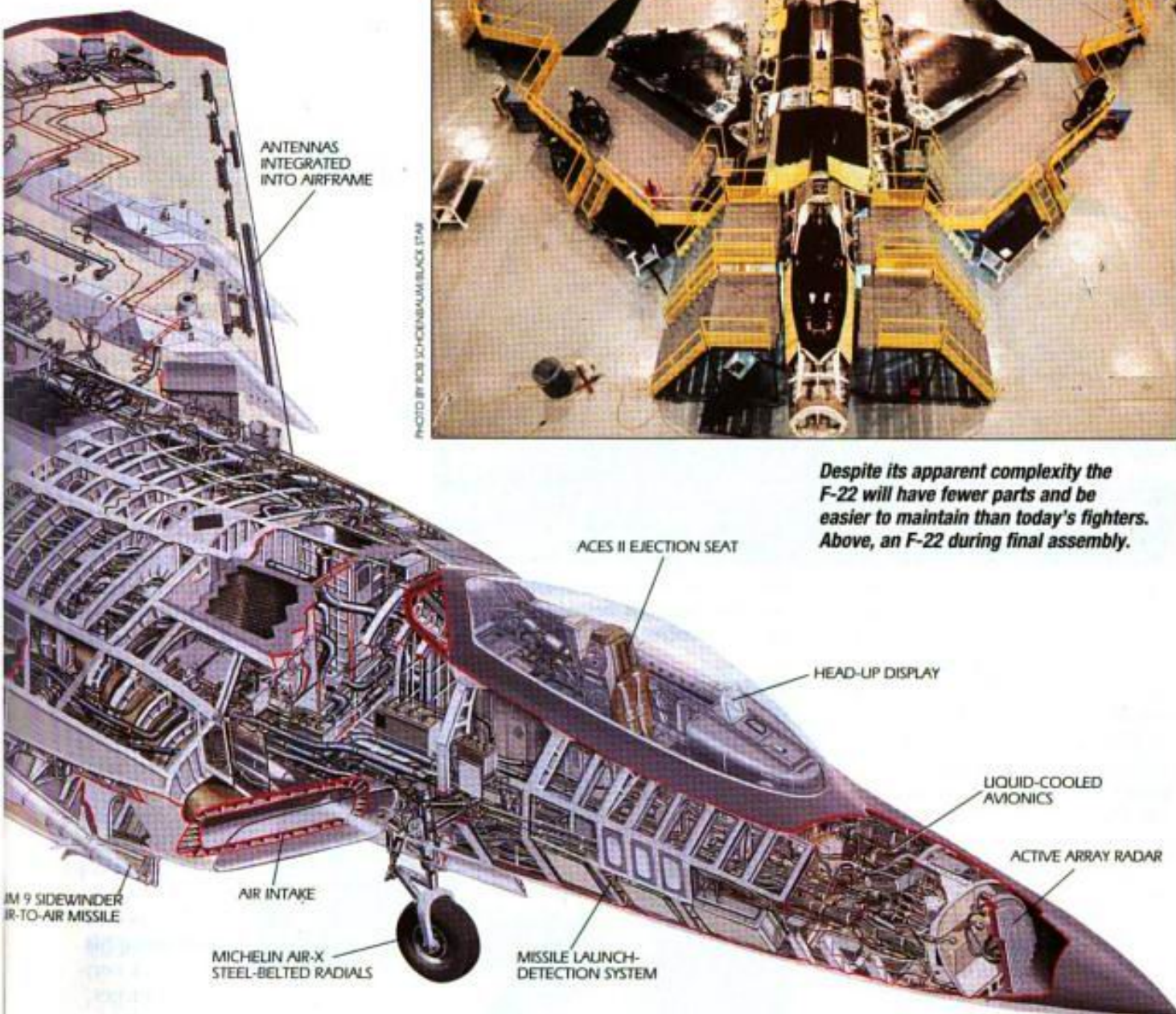
Into The Sky

The aircraft began flight trials in May of 1997. Eventually it could be joined by additional development and preproduction models, for a five-year program of flight and ground testing. Whether this amaz-

ing aircraft goes into full production remains an open question.

The Pentagon has already slashed costs in the F-22 program by slowing its development and reducing the planned fleet size to 438 aircraft. Still, with each aircraft valued at

"We have no desire to control the world. We have a great desire to see that no one else controls the world."



Despite its apparent complexity the F-22 will have fewer parts and be easier to maintain than today's fighters. Above, an F-22 during final assembly.

somewhere between \$70 million and a breathtaking \$198 million, depending on how costs are computed, the program is undeniably expensive—perhaps prohibitively so. Earlier this year, Congress pulled the plug on production money, but still allocated more than \$1 billion for continued development. So, as we go to press, the program continues to move forward.

The problem is that the airplane was supposed to trump the Soviets' next generation of weaponry. But now the Soviets are gone and Russia's military is barely able to put

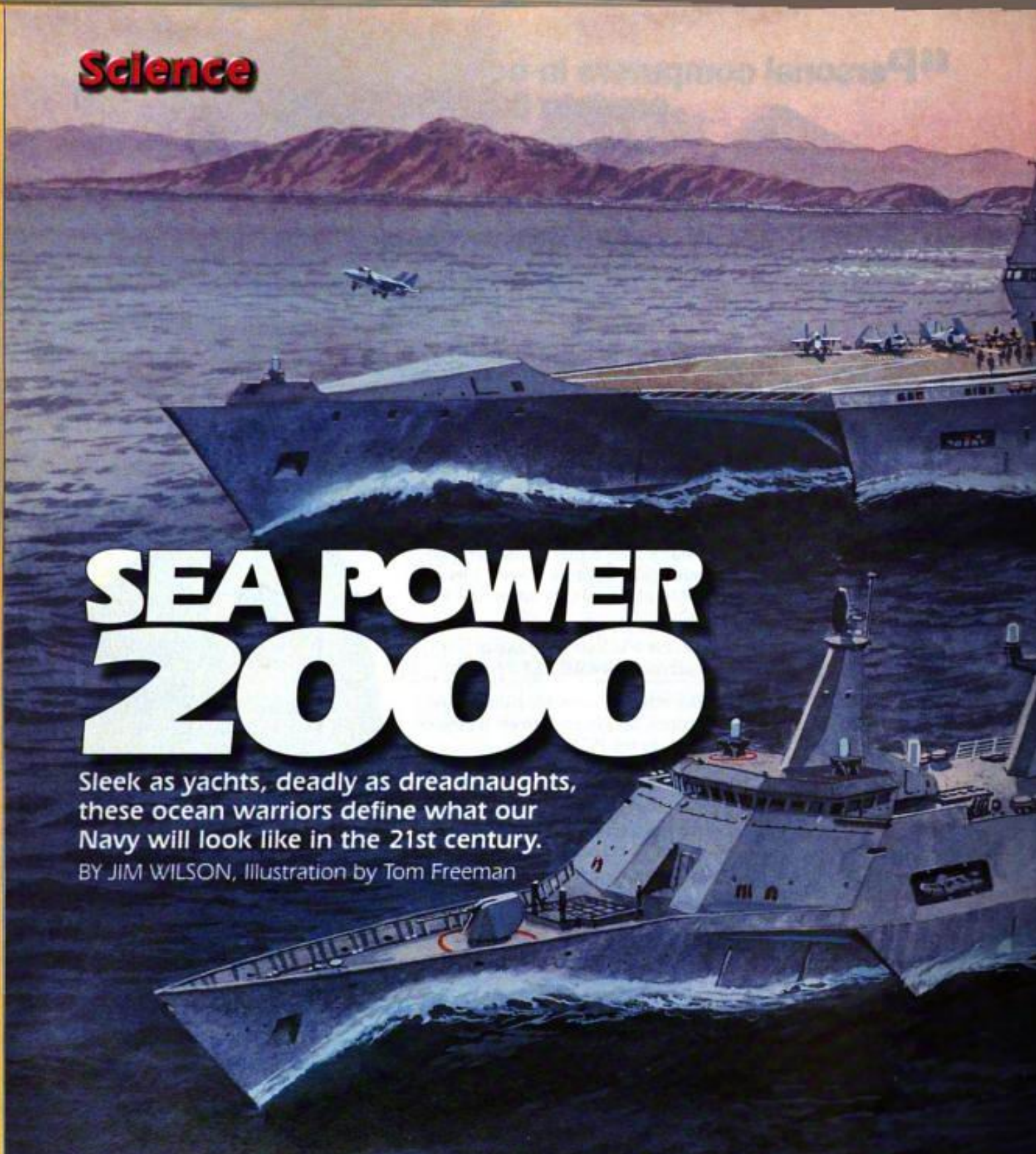
down internal conflicts. Many in Washington question the need to build the F-22 at all. The Pentagon also wants to develop the single-seat F/A-18E and the two-seat F/A-18F maritime strike attack Super Hornet, plus the Joint Strike Fighter. Budget cutters say there's not enough money to go around.

If the original F-22 survives and the current schedule remains intact, production could begin within a year, with the first unit becoming operational as early as 2004. The last aircraft would be delivered to the Air Force in 2012.

Unbeatable Technology

Constructed of 15 tons (its exact weight is classified) of titanium, aluminum, thermoplastic composites, fiberoptic lines, silicon, rubber and glass molded into a twin-tailed package, the jet measures 62 ft. 1 in. long, 44 ft. 6 in. wide, and 16 ft. 5 in. tall. It is the most sophisticated aircraft ever to have lifted off a runway.

To build this 21st century wonder, the Air Force drew upon all the knowledge gained in developing the F-117A stealth fighter, B-2 stealth bomber and even the SR-71 spy plane. Thanks to shaping and mate-



SEA POWER 2000

Sleek as yachts, deadly as dreadnaughts, these ocean warriors define what our Navy will look like in the 21st century.

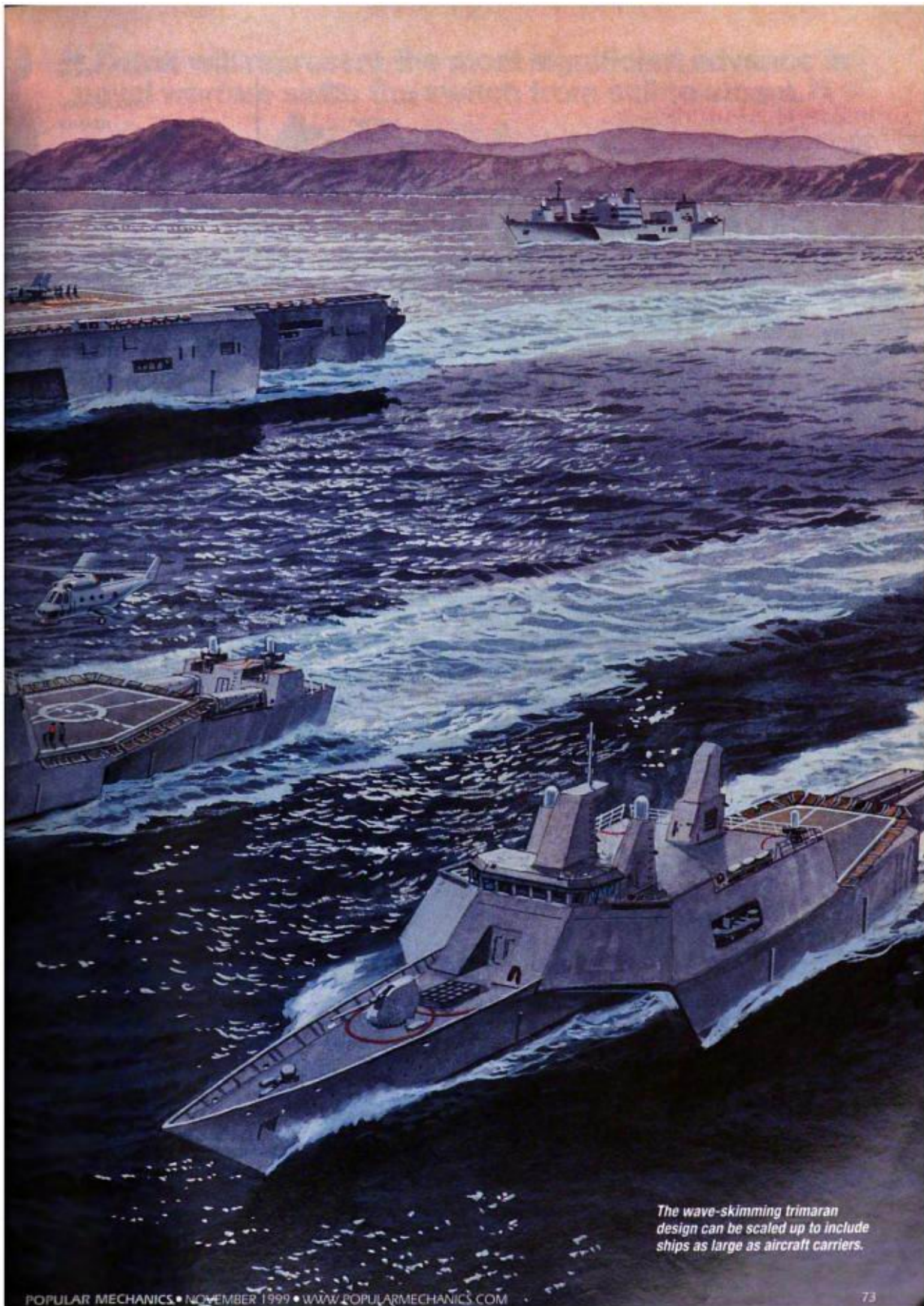
BY JIM WILSON, Illustration by Tom Freeman

▣ Shipbuilder Mike Carter

steps nimbly between two knee-high piles of half-inch steel plate. "Beautiful isn't it?" he asks, tracing a broad curve with his extended arm. "You don't get cuts like that with an acetylene torch." Fresh off a nearby plasma-arc cutting machine, the steel is so finely edged it almost appears polished. A dozen more stacks fill the football field-size workshop. It is easy to imagine we're standing inside a box filled with parts for a model boat kit, which in a manner of

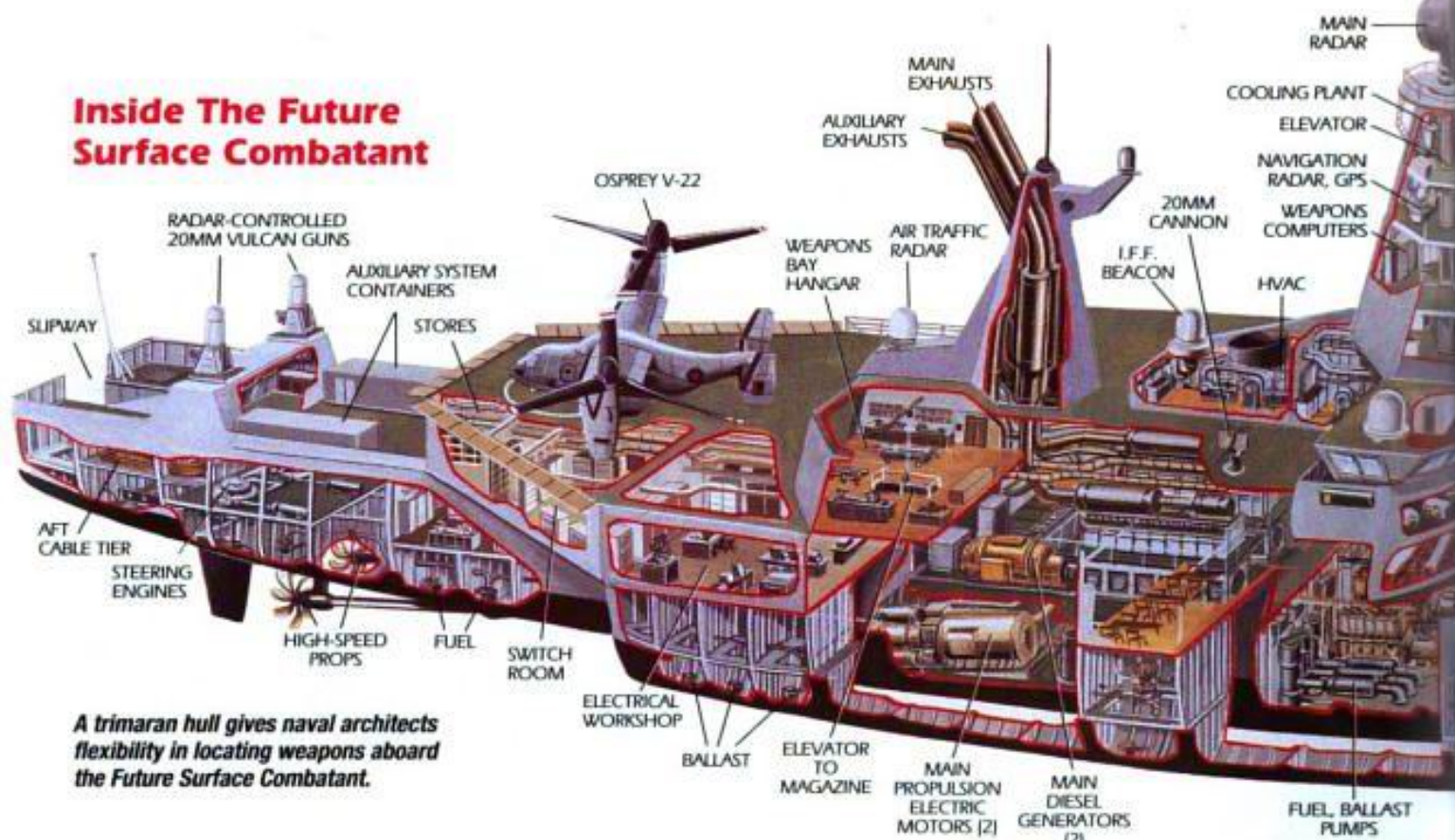
speaking, we are. POPULAR MECHANICS has been invited to the Vosper Thornycroft (VT) shipyard in Southampton, England, for an exclusive look at the construction of the *RV Triton*, the prototype for a new generation of warships: battle trimarans.

By next April, these precisely cut pieces will be welded into a finished ship measuring roughly 300 ft. long and about 66 ft. at the beam. Britain's Defence Evaluation and Research Agency (DERA) believes that the *Triton's* fast, fuel-efficient and highly stable three-hull design will represent the most significant advance in naval warfare since the switch from sail to steam.



The wave-skimming trimaran design can be scaled up to include ships as large as aircraft carriers.

Inside The Future Surface Combatant



A trimaran hull gives naval architects flexibility in locating weapons aboard the Future Surface Combatant.



Even with the first sea trials of this two-thirds-size demonstrator several months away, the Royal Navy is so convinced of the merits of the new design it is considering a full-size version of the *Triton* as a replacement for its 22- and 23-class frigates. DERA showed PM sketches for an entirely trimaran fleet, including aircraft carriers.

While the U.S. Navy isn't using Royal Navy superlatives just yet, it, too, is impressed. Much of the U.S. research program is classified, but the Navy has acknowledged that it

has signed a memorandum of understanding with DERA under which Uncle Sam will pay for a major portion of *Triton's* sea trials. The U.S. Coast Guard plans to evaluate a modified *Triton*-class craft as a replacement for Hamilton and Bear class cutters.

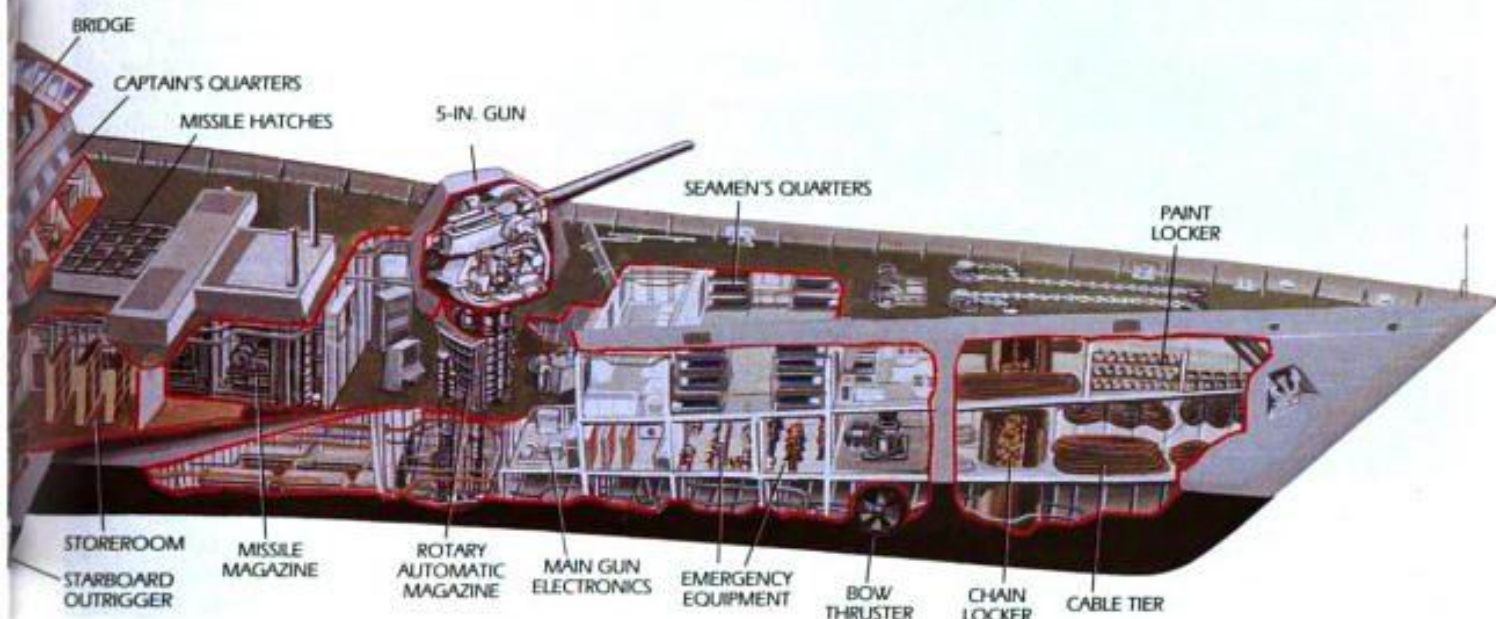
Three To One

"The possibility of using trimarans for warships was first studied by the Ministry of Defence sponsored professor at University College, London, in the late 1980s," explains

Chris Broadbent, the naval architect who is overseeing the project for DERA's Sea Systems Concepts and Integration Group in Fareham, England. Essentially, the students took an idea from the yachting community, the triple hull, and added the sort of armament required for a deep-water naval vessel. Impressed with what they saw, DERA and VT picked up the ball with follow-on research programs of their own.

Their computer models and water tank studies confirmed that a slender hull with outriggers could

"Triton will represent the most significant advance in naval warfare since the switch from sail to steam."



reduce drag by up to 20 percent compared to a single hull. The bottom line: "It will achieve 30 knots with about half the installed power required for the equivalent 83-meter monohull," says Broadbent. "The lower resistance will permit higher speeds to be achieved, or a reduced machinery fit leading to lower through-life costs."

The outriggers make the ship more stable, and give it a larger flight deck, which can be moved away from the stern and nearer amidships, allowing helicopters to operate under a wider range of sea conditions. Optional side-hull propulsion in the outriggers makes the ship more maneuverable. And if the ship does take a hit, the outriggers protect the inner hull, where the main powerplant is contained. "Survivability in general from weapons strikes will potentially be greatly improved," says Broadbent.

Different Needs

Although the British and the Americans are looking for different things in their next-generation warships, the trimaran design appears to please both. "The [British] Strategic Defence Review placed considerable emphasis on a fast response task group comprising larger, faster ro-ro [roll-on, roll-off]

vessels and ferries, which have evolved under commercial requirements," says Broadbent. "Ships transporting troops and equipment to a future area of conflict will be maintaining higher-than-convoy speeds in demanding sea states. It therefore becomes crucial for [combat] vessels to match that speed and sea-keeping ability."

The roles of Britain's first trimaran warships would include use as deterring patrols and in controlling the seas. In peacetime they would be used on antismuggling patrols, fisheries protection, search and rescue, disaster relief, research work and marine traffic control.

To perform these tasks, the Royal Navy envisions a faster, fully armed version of the *Triton*, which it calls the Future Surface Combatant (FSC). Capable of achieving speeds as high as 40 knots, the FSC would have a range of about 1500 nautical miles. Its crew would be small, consisting of nine officers, 21 senior ratings and 30 junior ratings. There would be additional room to berth 21 men undergoing sea training. The ship itself would be equipped for 21 days at sea. Or, as long as its 20 tons of fresh water and 90 tons of fuel oil held out.

The engines of the larger ship would be different from those on

Triton. One possible configuration, called the low installed power option, would use four marine diesel engines each rated at 3000 kw. Propulsion would be provided by two waterjets for cruising, each driven by a single diesel engine. One waterjet in the main hull would provide boost power driven by two diesel engines through a twin-input single-output gearbox.

Weapons on the FSC would include a medium-caliber gun, two small-caliber guns, two machine guns, medium-range surface-to-air missiles, surface-to-surface missiles and a torpedo launch system. To protect itself the FSC would be equipped with E/F, G or I band surveillance radar, an electronics warfare suite, and chaff and infrared decoy systems.

American Trimaran

The United States is less concerned about increasing the speed of military ships to escort fast merchant vessels. Its interests are more long range. "The U.S. in general is interested in innovative concepts. The trimaran concept has a lot of potential advantages," says Tom Cannon of the U.S. Naval Sea System Command, near Washington, D.C. He is the program manager for the joint U.S.-U.K. instrumented trimaran

"If you look at the way the U.S. Navy, all navies, are going, it is toward lower operating costs."



demonstrator. To see how well the idea works, the United States is placing 500 information-gathering sensors and a Trials Information System computer system aboard the *Triton*. During these trials, *Triton* will be manned by a commercial crew and research scientists.

"The idea is simply too good to pass by," says Cannon. "If you look at the way the U.S. Navy, all navies, are going, it is toward lower ship operating costs. If you can save

20 percent on fuel, you're really looking at something."

A second reason for the Navy's interest has to do with future propulsion systems. The Navy, like all branches of the service, is fighting a break-even battle with reenlistments. It sees the switch from steam systems, which are unique to each class of vessel, to electric propulsion, which could be used for all types of craft, as an important part of its serviceman-retention equa-

tion. In the future, a sailor trained to operate the propulsion system of a carrier could, for example, switch to a missile cruiser or possibly a submarine, something now difficult if not impossible. The ability to more easily change among ships over the course of a career is seen as a powerful incentive to reenlist.

Cannon believes that the earliest the new design might be applied is on the DD-21, an advanced land-attack destroyer, which is still in the early stages of development. Closely involved with this project, he rated the likelihood DD-21 would ride on a trimaran as a long shot.

Off The Shelf

Most everything aboard *Triton* will come off the shelves of commercial suppliers. Initially, VT's control subsidiary, VTC, has been given total responsibility for system design, integration and the procurement of propulsion machinery. Motors and controllers are being supplied by a European company, HMA of the Netherlands. The plant will consist of a pair of 2-megawatt diesel generators that feed a 3.5-megawatt electric motor that drives a single centerline shaft in the main hull.



The VP plasma-arc steel cutting system is so advanced, it even draws an ink-jet printed line showing where to weld.

Propellers in the side hulls will be driven by a pair of 350-kilowatt motors. The main generators will also energize the ship's auxiliary systems. The powerplant controllers and other systems will use View 2000, the Vosper multifunction workstation. Commercial, off-the-shelf open standard technology, it includes flat screens and zonal controllers dedicated to principal machinery areas including the main generators and motors, auxiliary



One possible configuration would be a vertical tube missile launcher that could pound targets hundreds of miles inland.

powerplant, damage control and propulsion control. A dual redundant fiberoptic ship databus will link the main workstations on the bridge with the machinery control room and the zone controllers.

"Besides its value as a trimaran demonstrator *Triton* will also provide the platform for the next step toward full electric propulsion," says Broadbent. To this end, *Triton* has been designed to allow for the installation of a permanent magnet main motor, a potential battery/fuel cell compartment and flight deck and engine room sites for future gas-turbine alternators.

In the United States, Newport News Shipbuilding (NNS), of Newport News, Va., and the General Dynamics (GD) Marine Propulsion Plant Team in Groton, Conn., are both developing integrated electric drive systems for the Navy.

The NNS system envisions a modular, 15 ft.-dia., 20-megawatt permanent magnet motor. It could be scaled up to 30 and 40 megawatts by adding modular magnets

to lengthen the rotor and corresponding segmented stator blocks. Each stator block would be mated to its own modular motor drive power controller. "This modular design makes the system easier and less expensive to maintain, and better able to survive battle damage," NSS manager Thomas Dade tells PM. The motor would be powered by a modified jet turbine engine, directly coupled to a generator with different voltage outputs for the powerplant and other ship service requirements, thus eliminating the need for both reduction gearing and transformers.

GD plans to employ radial air-gap permanent magnet motors driven by modular series-parallel motor drives. "These have been demonstrated at one-quarter scale, representing the most powerful permanent magnet motor system in the world," says GD's project manager, Ed Thaxton. The system

distributes medium voltage (5 to 15 kilovolts) power, using commercially derived vacuum switchgear that is one-half the size of commercial equipment. Power is supplied with a generator directly coupled to an aircraft-derived gas turbine. Ship service power would be supplied directly from the propulsion system.

Sea Trials

Regardless of their plans for future trimaran hulls, admirals around the world have their eyes on the *Triton*'s sea trials, which will begin next fall.

Rarely will the spotlight have shone more brightly on sea trials. Most modern weapons—small arms, artillery, tanks, even aircraft—have been the product of a slow but steady evolution. Not so with naval warfare where new types of ships—aircraft carriers and submarines to mention just two—routinely usher in new eras in sea power. Looking back from 50 years in the future, *Triton* just might be remembered as the 21st century ship that rendered 20th century fleets obsolete. **PM**

For More On Science

Check the Science channel on the PMZone Web site at <http://popularmechanics.com/popmech/sci/1HOMESCI.html>



► With the end of World War

II, the global order had truly changed. Europe lay in smoldering ruins. Intelligence reports hinted our former Soviet allies had learned the secret of building an atom bomb. America had a fearsome atomic arsenal. But by itself it posed no deterrent to Soviet aggression. To maintain global stability Uncle Sam needed to prove it could press its nuclear spear into the very heart of Mother Russia.

DEFENSE

It was with this new, never before imagined mission in mind that Pentair planners took pen to paper and

in 1945 set out to design an entirely new type of strategic bomber. The aircraft needed an unrefueled range of up to 10,000 miles, or nearly twice the range of the original nuclear bomber, the B-29 "Enola Gay," and enough internal capacity to contain the limousine-size nuclear bomb, which in those early days measured 8 ft. in diameter and stretched 25 ft. from nose cone to tail. The contract for this new machine went to Boeing, and in November 1951, the first production prototype rolled out the factory doors.

There had never been anything like it. Nearly 160 ft. long and supported by swept wings spanning 185 ft., it weighed nearly a half million pounds fully loaded. Four

NEW LIFE FOR BUFF

Older than its pilots, the B-52 gets ready to fly for 100 years.

BY WILLIAM GARVEY, Photos by Randy Jolly

twin-wheel landing trucks supported its fuselage. Outriggers supported its drooping, fuel-laden wings. To heft the giant, the designers slung eight Pratt & Whitney J57 turbojets in four pods below the wings. Generating more than 100,000 pounds of thrust, the Pratts shoved the monster along at a maximum 595 mph. The price? A breathtaking \$8 million per copy.

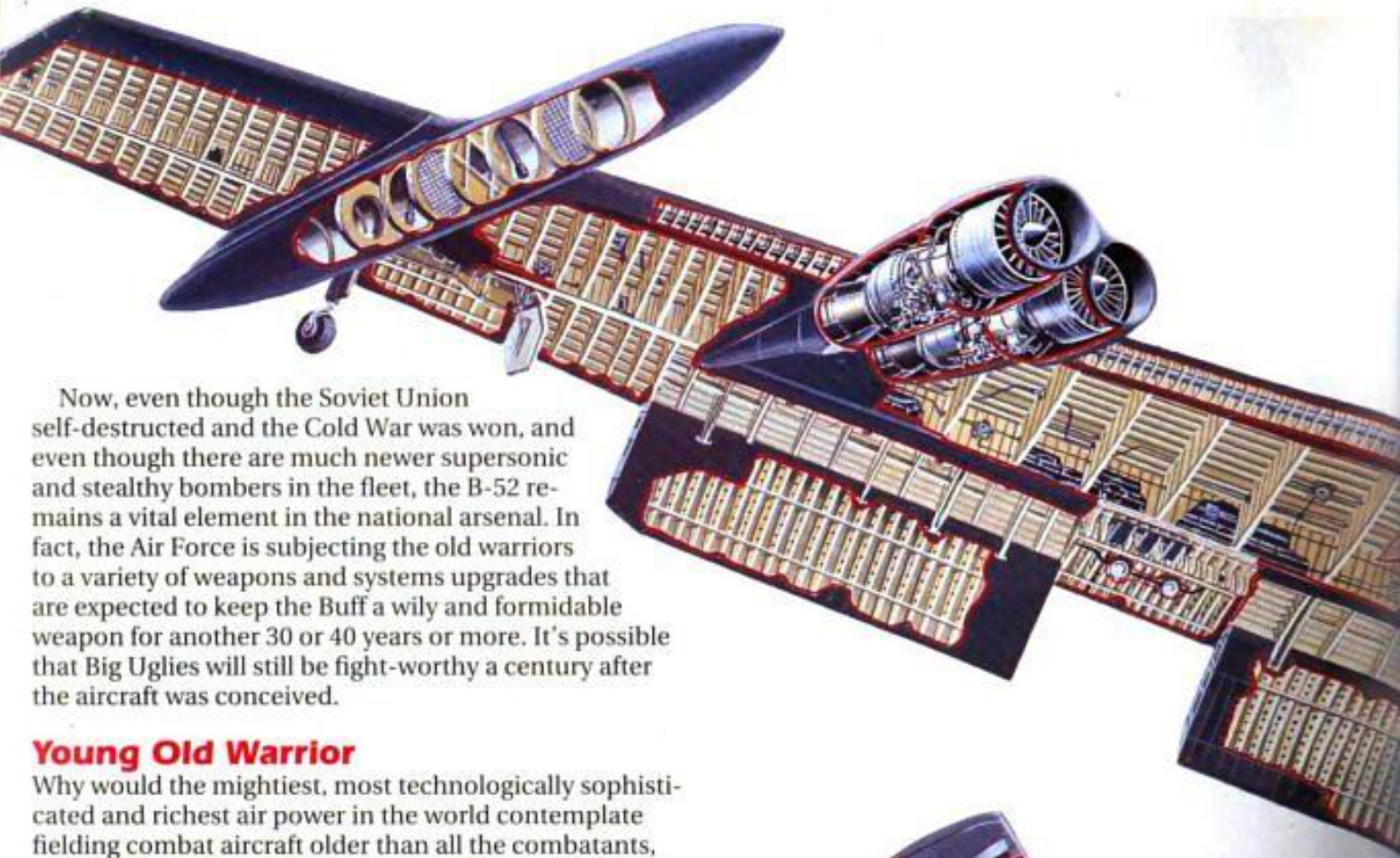
Its official name was the B-52 Stratofortress. Among aircrews its immensity and its hulking lethality soon earned it the nickname "Buff," short for Big, Ugly, Fat Fellow (or less printable variations of that theme).



From the outset, it was an extraordinary airplane, worthy of its cataclysmic mission.

The Stratofortress took up duty as America's nuclear sentinel in the mid-1950s. To avoid being caught on the ground by a surprise attack, the United States kept B-52s carrying nuclear bombs airborne above American territory 24 hours a day for more than a decade. Those flights ended in the late 1960s, but nuclear-equipped Buffs continued on alert until 1991.

The bomber never had to fly the mission for which it was designed—thanks in no small measure to the fact that it could. Deterrence worked. World War III never erupted.



Now, even though the Soviet Union self-destructed and the Cold War was won, and even though there are much newer supersonic and stealthy bombers in the fleet, the B-52 remains a vital element in the national arsenal. In fact, the Air Force is subjecting the old warriors to a variety of weapons and systems upgrades that are expected to keep the Buff a wily and formidable weapon for another 30 or 40 years or more. It's possible that Big Uglies will still be fight-worthy a century after the aircraft was conceived.

Young Old Warrior

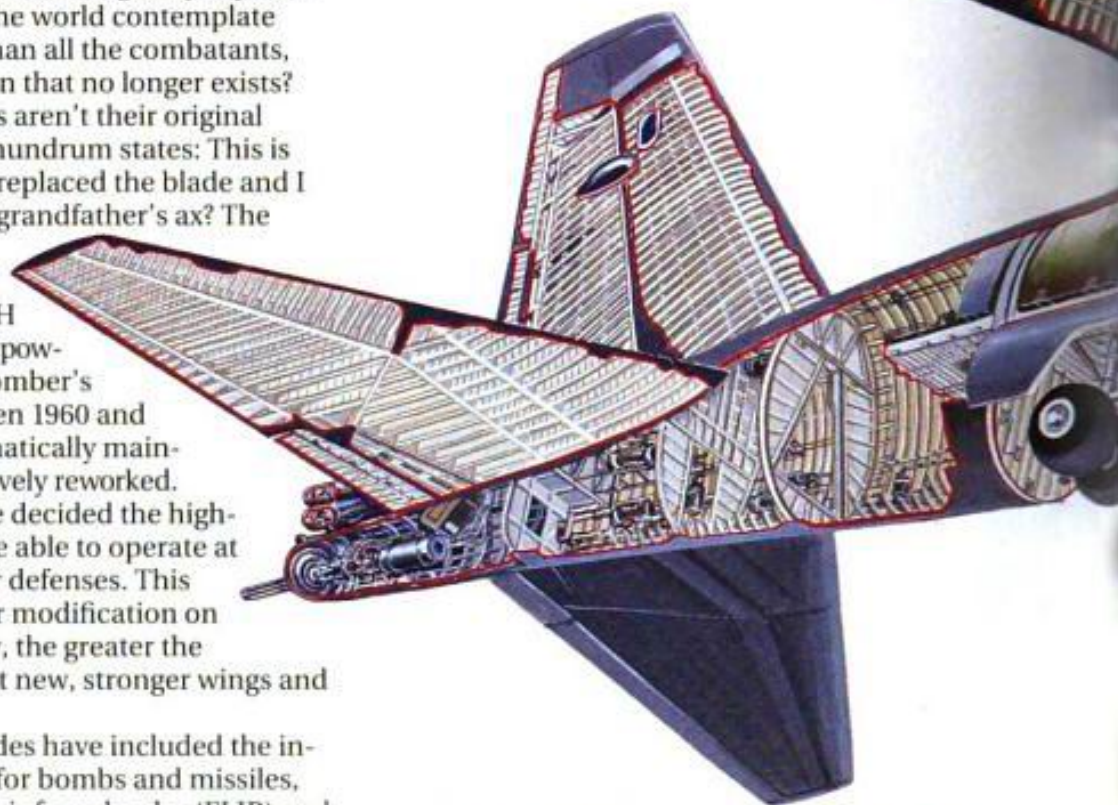
Why would the mightiest, most technologically sophisticated and richest air power in the world contemplate fielding combat aircraft older than all the combatants, machines designed for a mission that no longer exists? The answer is that today's B-52s aren't their original selves. An old philosophical conundrum states: This is my grandfather's ax. My father replaced the blade and I replaced the handle. Is this my grandfather's ax? The B-52 is a lot like that ax.

The B-52s remaining on active duty are all TF33-powered H models, making them the most powerful and the youngest in the bomber's series, having been built between 1960 and 1962. All of the airplanes are fanatically maintained and all have been extensively reworked.

In the late 1960s the Air Force decided the high-altitude bombers should also be able to operate at low altitudes to evade Soviet air defenses. This change of tactics forced a major modification on the fleet, since the lower you fly, the greater the turbulence. And so the Buffs got new, stronger wings and reinforced fuselages.

Other changes over the decades have included the installation of underwing pylons for bombs and missiles, the addition of forward-looking infrared radar (FLIR) and low-light television, and the modification of the bomb bay to accommodate conventional "iron" bombs, incendiaries and groups of smaller, though no less lethal, nuclear bombs. During the Vietnam War, the Big Uglies unloaded up to 70,000 pounds of ordnance on the unfortunates below.

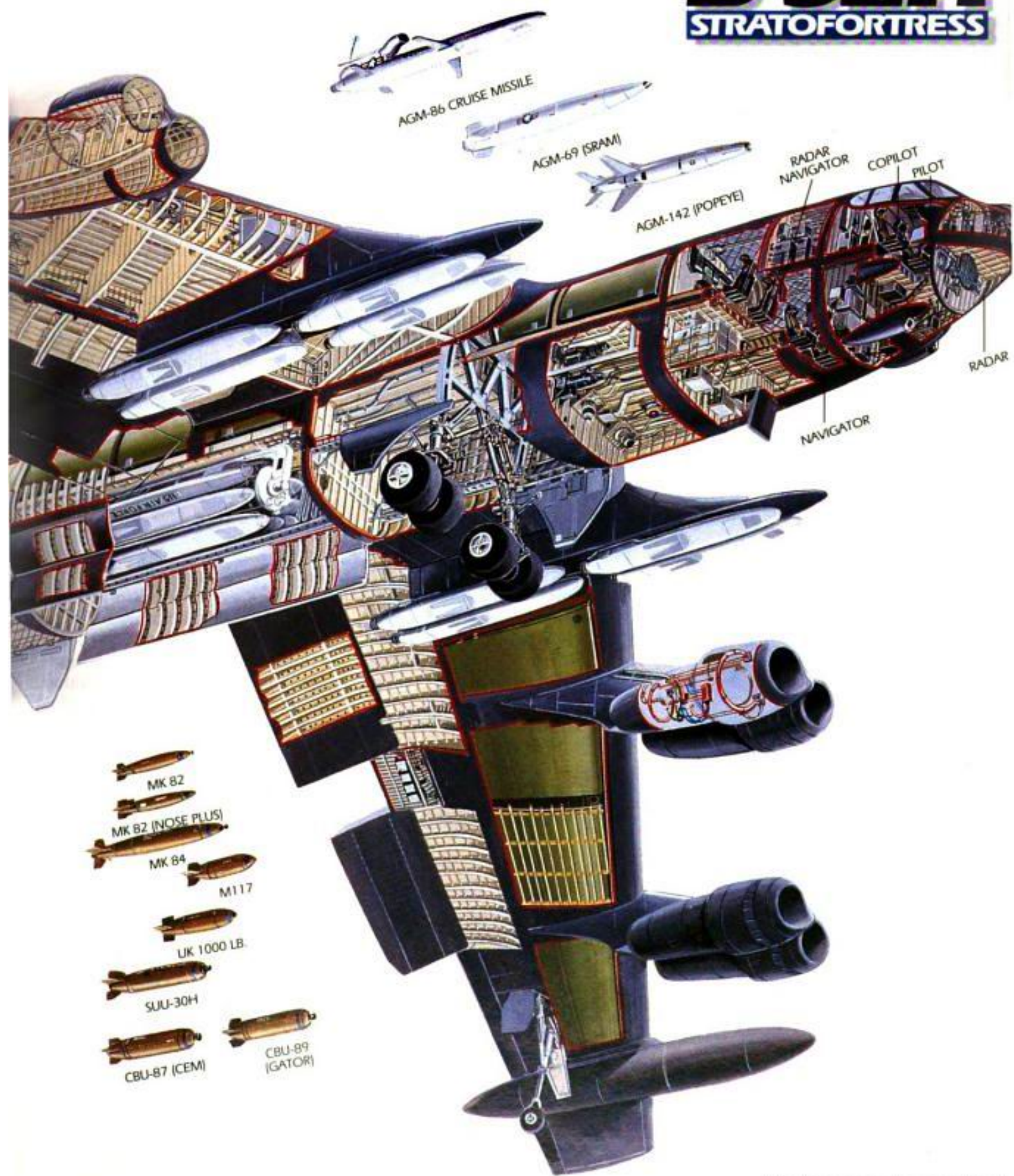
Although Boeing built 744 B-52s, by the start of this year only 94 remained in active service with the U.S. Air Force (NASA, which owns one B model, is the only other operator) and that number could be whittled further as the Pentagon's budget contracts. Still, no one is suggesting all the old war horses should be put to pasture—for good reason.



“The Buff’s value was made clear during the Gulf War and Desert Fox. The B-52 turned out the lights in Baghdad.”

B-52H

STRATOFORTRESS





Photos by the author

New challenge on the Grand Prix circuit:

What's behind those four little wheels?

The six-wheel Formula One racer is fast and furious, and has proven itself in only one season . . . but it's still funny-looking!

by Bill Hartford
AUTO EDITOR

The Grand Prix circus had come full circle and was back in the United States for the next to the last race of the '76 season. Five hours at 55 and I was at the Glen again.

In Watkins Glen, N.Y., everyone is a race fan—at least once a year. Even the street signs are in the shape of little race cars. But they hark back to the glorious days when the cars roared through the streets and in no way do the signs resemble today's Formula One cars with their wings and wide tires . . . and none of them are in the shape of a six-wheel car!

Six wheels . . . for a Grand Prix car—the most sophisticated and exotic of all racing machines? The front four wheels looked even smaller than I remembered them when I first saw the car at the Swedish Grand Prix. There, Ken Tyrrell's two drivers stole the show: Jody Scheckter and Patrick Depailler, one-two in the race, beamed on the winners' circle while Niki Lauda was last to swig



Nosing in on the six-wheeler (above), you can see details; mounting tiny, 10-inch wheels is easy for Tyrrell team's mechanic. At top: Jody Scheckter speeds to victory at the '76 Swedish Grand Prix.

the champagne—he was third. James Hunt, destined to win the 1976 World Driving Championship from Lauda in Japan by a single point, was fifth and at that time still way behind Niki in points.

But now it was the Glen, and race day broke clear and cold after days of rain. The hills around the circuit were thick with fans, all watching, waiting for 26 cars to thunder into view all bunched and battling for that No. 1 slot. From the chicane at the esses I could hear the start. Within seconds Scheckter was snapping the six-wheeler around the striped curbing and leading the pack up the hill. After some dueling, though, Hunt took the lead and kept it. Jody collected six points for a second-place finish. That made it 49 for the season. Depailler, in the second six-wheeler, finished out of the points. In Japan, however, the last GP of '76, he finished second, drafting Mario Andretti a lap down as the pair passed the checkered

Designed by Derek Gardner, fielded by Ken Tyrrell and sponsored by Elf, the six-wheel Grand Prix cars carried Jody Scheckter and Patrick Depailler to third and fourth-place finishes for the 1976 World Driving Championship.



flag. He wound up with 39 points for the season, fourth in the drivers' standings.

What it all adds up to is an extraordinary performance for a new GP car in its first year of competition. The whole idea started with Derek Gardner, the racing car designer for the Tyrrell team. What he wanted to do was improve the aerodynamics by lowering the front profile in order to reduce turbulence and drag and be faster on the straights. You can do that by using smaller wheels, but how do you maintain the necessary cornering force in the front? Simple: four wheels instead of two. Their size was determined by specifying the same degree of road-holding that two larger wheels would provide.

Chuckles turned to cheers

Gardner designed a car that had fans chuckling early in the season, but cheering as it started finishing

in the money. It didn't even take long to sort out the problems unique to the six-wheel design. Front-end geometry and suspension—a double wishbone—was easy enough, the only variable being the track angle for the two sets of wheels. Very little difference is felt by the driver whether the angle is the same or whether the car runs with the front set of wheels turning slightly more than the rear set, as shown by angles A and B on the opposite page.

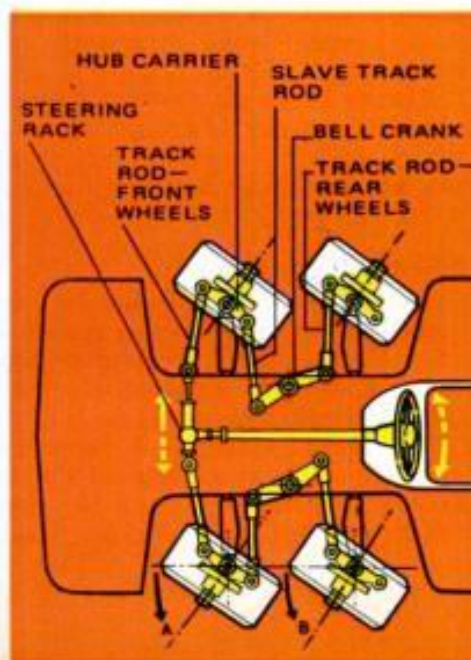
Steering required some attention. With four small tires there's more

self-aligning torque and it took some testing by Scheckter and Depailler to arrive at the best steering ratio (which is quite high but preferred by both drivers). Brakes are venti-



PM art: Ed Valigursky

Operation of the four front steering wheels is deceptively simple. The steering rack turns the front set of wheels in the conventional manner by means of the front track rods. Attached to the rear of the hub carriers, however, are the slave track rods which are connected to the front ends of the bell cranks that pivot as shown at right. Attached to the other end of the bell cranks are the rear track rods. They are attached to the hub carriers of the rear set of wheels to turn them. In turns, the front wheels turn slightly farther than the rears (track angle A less than angle B). Suspension is a conventional double wishbone setup.



lated discs on both sets of front wheels, as shown above, and were perfect as they came off the drawing board—no reworking of balance, displacement or pedal effort needed.

The relatively short wheelbase (wheelbases, actually!) acts to lower the car's polar moment of inertia. Simply, this term refers to the ease or difficulty with which a race car (or any vehicle) can be made to change direction—either by a steering input, or by hitting a bump or taking a side wind. Too high a polar moment and the car's a stone, too low and it's excessively twitchy. The early project car was too twitchy

(Please turn to page 104)

CITY AT SEA

Nearly a mile long and 25 stories high, *Freedom* will be the largest vessel to ever sail the seven seas.

BY JIM WILSON, Science/Technology Editor
PM Illustrations by John Batchelor

● Norman L. Nixon loves to talk about the enormity of it all. "Walk in a straight line for about 12 minutes," he says. "If you don't dawdle, you'll cover slightly less than a mile. Now, make a right turn and walk beyond the length of two football fields. Duplicate these lines to make a rectangle, then look up to the height of a 25-story building. This is what *Freedom* will be." Listening to him talk about it, you begin to understand why Nixon doesn't refer to *Freedom Ship* as the world's largest vessel, but the



Freedom will dwarf the *Queen Elizabeth II* and become a permanent home for 50,000 people.

span a distance 15 times its height. "A ship with an effective depth of 80 ft. of hull [measured from keel to main deck] can theoretically span a maximum of 1200 ft.," Nixon says. "On *Freedom*, the effective beam runs 350 ft., from the bottom of the ship to the aircraft runway." The result is a 4320-ft.-long floating beam that draws 37 ft. of water as it rides atop waves, rather than plowing through them.

"We're not doing anything new," Nixon says. "We've taken technologies used in one area and applied them here." Indeed, Nixon says that during World War II the Navy used floating docks longer than *Freedom*. More recently, Kvaerner, the Norwegian ship and oil platform builder, proposed that the U.S. Department of Defense build a 5249-ft. floating airfield capable of supporting 10,000 troops. Called *SeaBase*, it would use Kvaerner's patented linking system to join three giant semi-submersible drilling rigs into a landing field.

Although similar in scope to these massive seagoing projects, *Freedom* actually began as

an equally ambitious project on land. "We were on the verge of building an entirely new city on the 50-sq.-mile uninhabited island of East Caicos, south of the Bahamas. It was to serve as a modern Hong Kong," says Nixon. "Had the then chief minister not lost his reelection bid, we would probably be at work on the island today. In retrospect, the loss of this opportunity appears to have been the best thing that could have happened."

When a search of natural and manmade islands failed to turn up a suitable alternate location to East Caicos, one of *Freedom* city's original backers suggested building an island that could visit different countries each month. Strange as this suggestion seemed, it was something Nixon had actually done before. During

the 1980s, he was part of a team of engineers who built a \$1 billion modular ethylene plant in Japan and then towed it as more than 100 modules to Saudi Arabia, where it was reassembled. Encouraged by Nixon's hands-on experience in seagoing modular construction and the fact that he has licenses to practice structural, electrical, sanitary and civil engineering, his early supporters elected to follow his dream to sea. "And so," he says, "the *Freedom Ship* project was born."

Freedom promises to be as different from today's oceangoing vessels as the *Queen Elizabeth II* is from the *Mayflower*. Starting with the keel, *Freedom* doesn't have one. This backbone is missing because *Freedom* is constructed of 520 airtight steel cells.



Each will measure 80 ft. tall. Depending upon its location, each will be 50 to 100 ft. wide and 50 to 120 ft. long. Assembled ashore on rails, they will be bolted together to form base units, each about 300 by 400 ft. These will then be floated out to sea and joined to form the completed base.

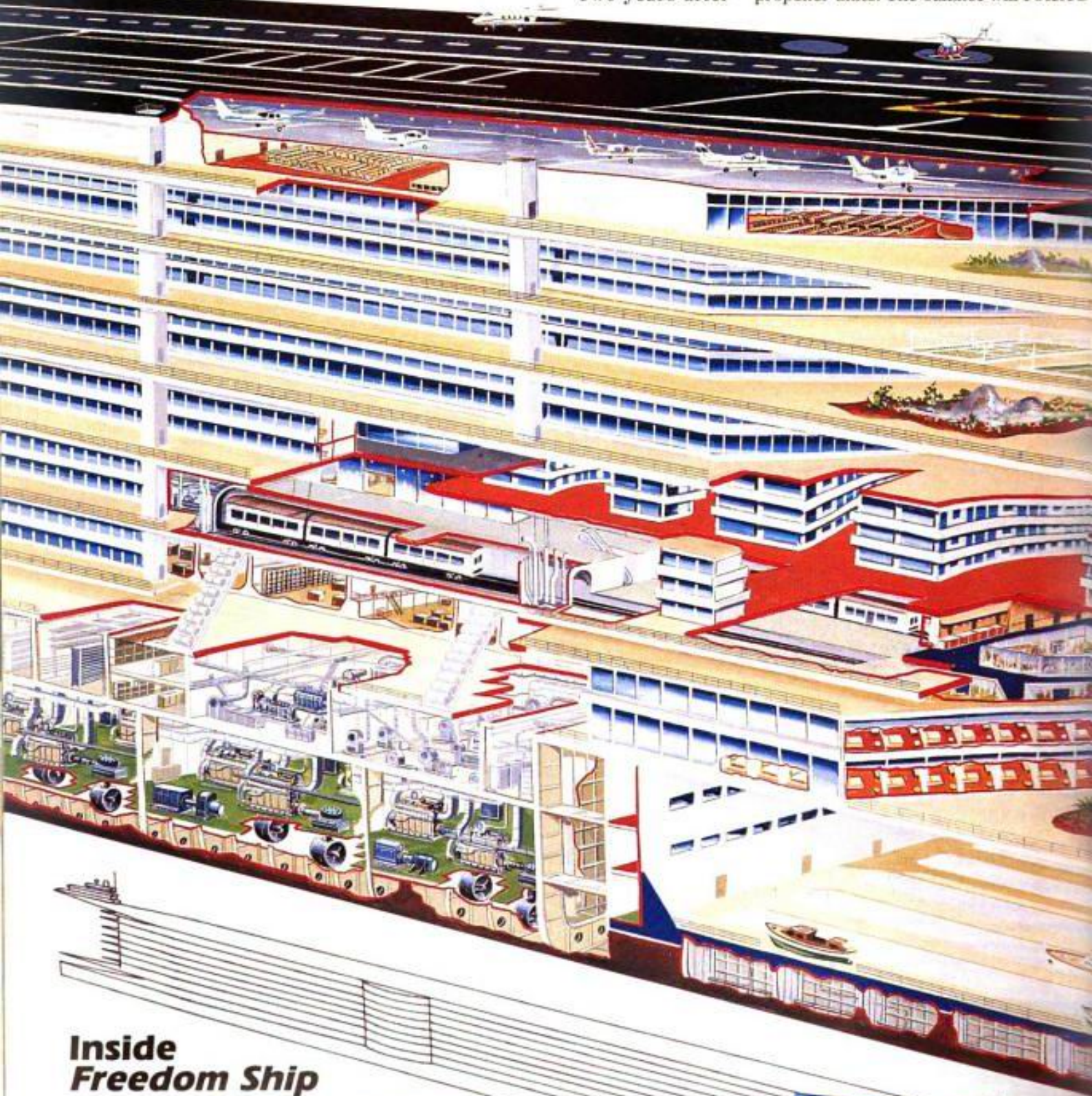
About 10 months after the start of construction on the first air-

tight cell, three base units will have been assembled at sea. At this point, the tempo of construction will increase. Meanwhile, on shore, four assembly lines will be dedicated to building airtight cells. At sea, work will begin on the 25-story superstructure. By the 17-month mark, the last base unit will be bolted in place and the 25th level completed.

Two years after

the start of construction, 4000 of *Freedom's* planned 21,000 units will be ready for occupancy. Her boilers will be fired up and she will set sail.

Well, not exactly. *Freedom* won't have the sort of boilers you find on traditional ships. She will be propelled by 3700-hp motorized units protruding through 100 of her watertight cells. About half of these will be shrouded propeller units. The balance will rotate



Inside Freedom Ship

Two of the most striking differences between *Freedom* and existing cruise ships are its jet-capable landing strips and the marina. The cutaway of the highlighted area (above) shows that the interior will be designed more like an urban area, with open spaces and transportation links, than a traditional ship. The view of the marina promises to be especially spectacular during heavy storms. Because *Freedom* will ride on top of the waves, residents will be able to look down at the troughs dozens of feet below.

AREA
ENLARGED
ABOVE

360°, like those used on tugboats. At about \$1 million each, these are among the world's most expensive marine powerplants. But, again, thinking like an engineer first and architect second, Nixon sees their cost as a bargain. This is because they can be linked to a central PC-type computer system. The helm thus becomes a joystick. And even this isn't necessary. Using GPS, *Freedom's* captain could simply sketch the ship's route on a touch-screen and the \$6 billion ship would find its own way. Theoretically.

park and recreation areas. Nixon has calculated that the resident population can support its own local economy, which means that residents will, in many cases, also be operating businesses at sea, in malls throughout the length of the ship.

As with a land-based city, these amenities and businesses will not appear overnight. The construction schedule calls for *Freedom* to set sail on its first 2-

to furnish blueprints of the completed ship. "Ships are designed by naval architects who then turn them over to structural engineers. We began with the structural engineering and will let the architects make it pretty," he says. In retrospect, this turned out to be a good strategy.

"We originally estimated the average condo sales price would be \$250,000. But it is averaging over \$800,000 per unit," Nixon says. To slow the sale of the most expensive units—those facing the ocean—Nixon recently jacked up the price by 20%.

But, he says, they are still out-selling the less expensive interior units, which cost as little as \$24,000, by 10 to 1. Nixon has responded by adding another level. He also has added a second airstrip atop the ship and increased its capacity to handle 100,000-pound jets.

The "we" to which Nixon repeatedly refers as he describes *Freedom* is a team of 24 engineers and consultants who work with his Sarasota-based firm, Engineering Solutions, via Internet connections.

Like Nixon, many are technical experts from outside naval architecture. Their backgrounds have spurred on a number of decidedly non-nautical solutions to the problems of living at sea. For example, rather than burning the cheapest marine fuel, Nixon has specified engines that require more expensive diesel fuel. His rationale is that this cleaner-burning fuel will reduce long-term engine maintenance costs and create less pollution.

Freedom's proposed environmental systems are also a major break with tradition. For instance, sewage won't be flushed into the ocean. Instead, sanitary waste will be incinerated in electric toilets. "This eliminates the need for wastewater treatment," says Nixon. It is also the reason for a no-pets policy for residents and visitors. Graywater from washing will be recycled into drinking water. Recycling is cheaper than desalinating seawater. Waste heat from the engines will be recycled for spinning generators and heating space and hot water. Nixon even has a plan to turn trash into cash. *Freedom* is so large that it will be possible to store recyclable materials until the ship reaches a port where the scrap will fetch the highest price.

As this issue of PM went to press, Nixon said he was evaluating bids from shipyards in South Africa, Brazil, Poland and Mexico in preparation for beginning construction this year. If the project develops as planned, we'll be filing our next progress report on it from sea. **PM**



Once under way, life aboard *Freedom* will be more like living in a bustling city than being on a vacation cruise. Because of its size, the ship will have its own railway system. Courtyards set about its decks will create interior

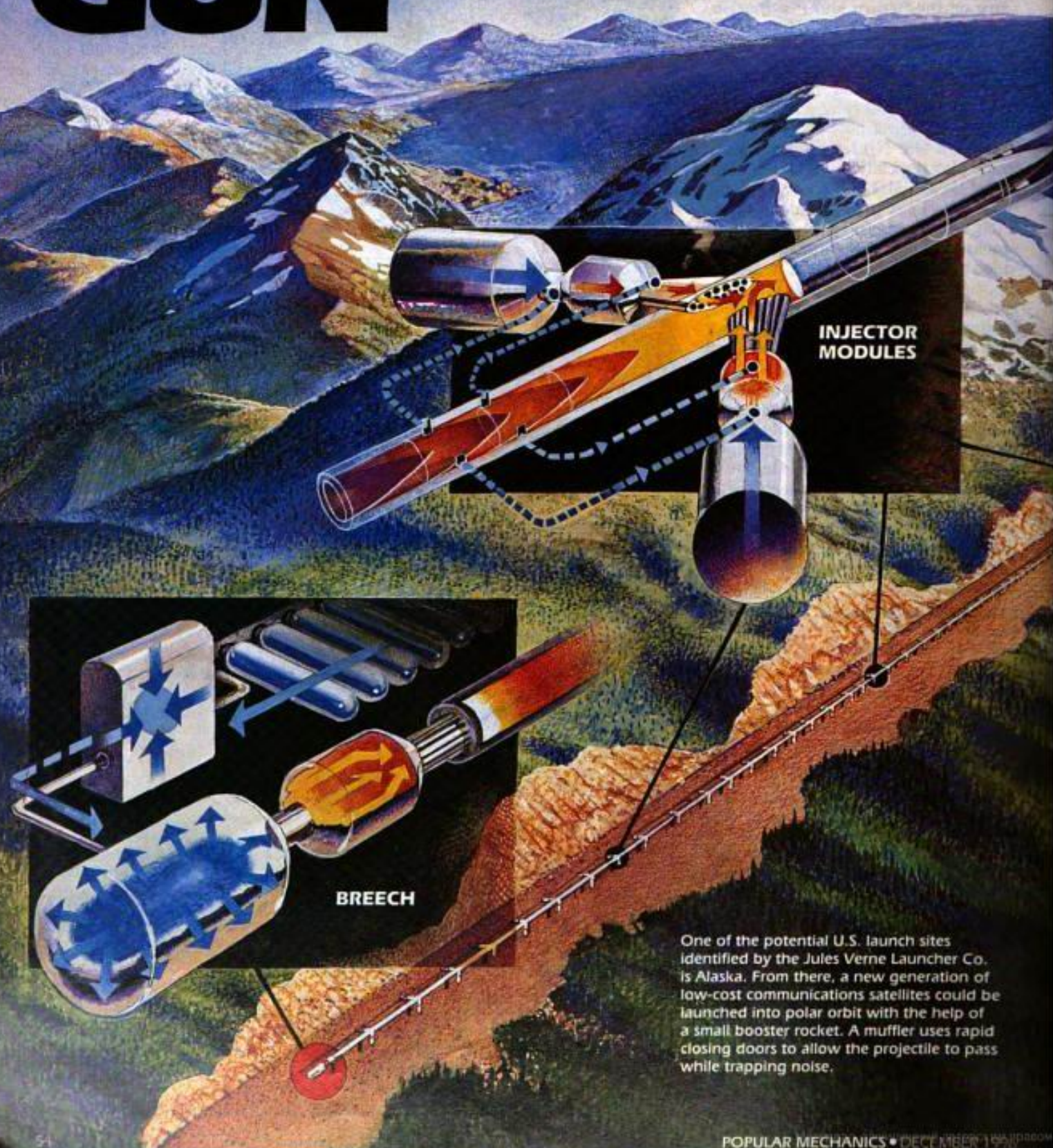
year cruise as soon as its first 4000 units are finished.

The rest of the ship will be built at sea. This is strictly an economic decision. "*Freedom* will attract labor from around the world," says Nixon. "The cost of the ship's labor force will be quite low by developed nations' standards."

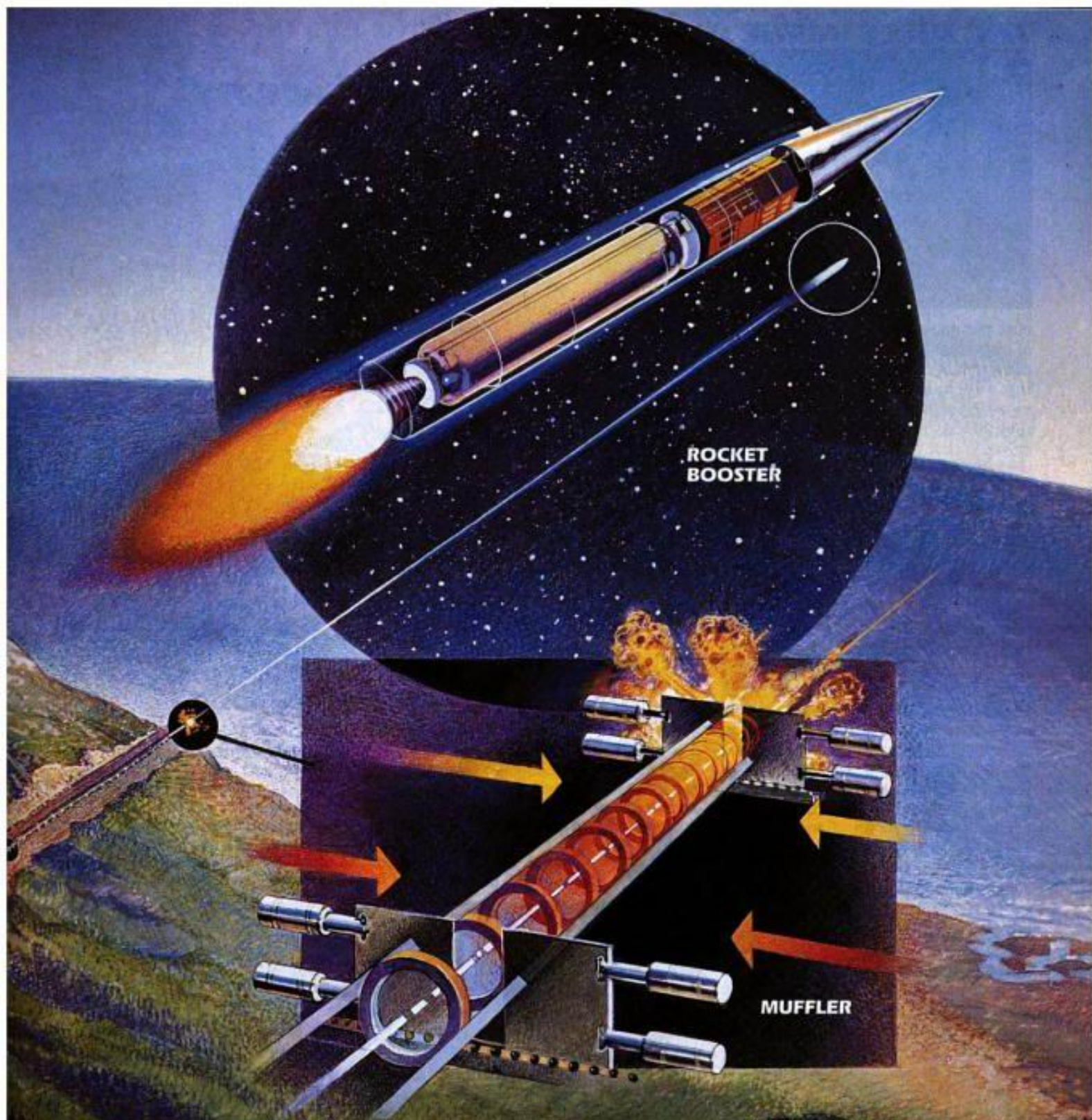
By now, Nixon has grown accustomed to criticism from the mainstream shipbuilding community. One of its first complaints was his inability

THE JULES VERNE GUN

An ambitious plan to change the way we launch satellites will fulfill the science-fiction writer's dream.



One of the potential U.S. launch sites identified by the Jules Verne Launcher Co. is Alaska. From there, a new generation of low-cost communications satellites could be launched into polar orbit with the help of a small booster rocket. A muffler uses rapid closing doors to allow the projectile to pass while trapping noise.



BY SCOTT R. GOURLEY, PM Illustrations by Harold Smelcer

• In his 1865 novel *From The Earth To The Moon*, author Jules Verne describes a post-Civil War society in which the convened members of the fictitious Baltimore Gun Club lament the sudden lack of artillery activities. Their boredom is soon broken by a speech from the club's president, who outlines a bold plan to use a giant cannon to fire a projectile to the Moon. One of the fictional club members awed by the plan is named Tom Hunter. Coincidentally, a very real visionary with the same last name may make author Verne's fantasy come true.

"Jules Verne was a true visionary in an era when you needed visionaries," explains John Hunter. "Now, the

problem is that we have too many visionaries and not enough doers." Hunter is standing in his cluttered Southern California office, where he has just drawn a diagram of comparative escape velocities on the blackboard. As president and founder of the Jules Verne Launcher Co., Hunter is combining Verne's vision with his own actions. Quite simply, he intends to use gas-powered launchers as an effective and inexpensive way of propelling satellites into orbit.

Hunter's quest began when he started working at Lawrence Livermore National Laboratory (LLNL) in 1985. One of his first projects at the lab involved the concept of an electromagnetic space launcher: "The

THE JULES VERNE GUN



SHARP TEST FACILITY

cost per joule of just about any kind of electric gun is so high that it's basically prohibitive," Hunter says. During a technical discussion at Livermore Lab, it was suggested that he look at the potential of "gas guns," systems that utilize a pump tube filled with heated and pressurized gas to drive projectiles at extremely high velocities. In fact, Hunter's search of the library database revealed that a NASA gas gun had achieved a projectile speed of 6.84 miles per second back in 1966. But he knew that higher velocity was needed.

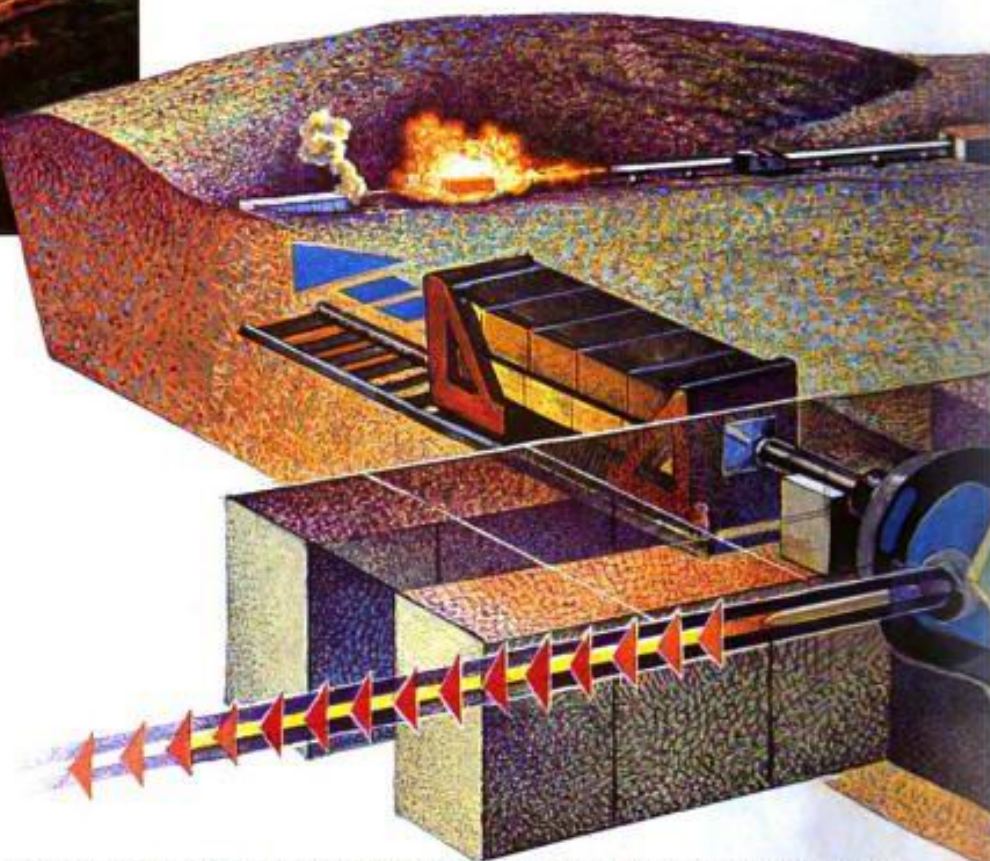
"At that point I knew, just like particle theory, that 99% of the people were just going along the well-worn path because someone had money or a cool idea. But they weren't being rigorous thinkers about solving the problem."

The solution that emerged involved the use of a gas gun with multiple injectors. Hunter's computer simulations suggested that such a system would work very well. "The velocities I was getting to were much higher than had ever been done before with conventional gas guns."

Hunter then conducted a 2-month lab project to demonstrate the anti-tank potential of a single-stage hydrogen gas gun operating at room temperature. "I got 1.5 miles per second. The results were within 1% of my code predictions on six data points." Based on the computer model's accuracy and the quick completion of the project, Hunter was funded for a 3-month effort to develop a 2-stage gas-gun precursor to a space launcher. The effort produced a 10-ft.-long gas gun that achieved a firing velocity of 5 miles per second.

"[That] still exceeds the velocity record for any rail gun ever built," Hunter says. "Gas guns routinely achieve 5 miles per second. That's what's so phenomenal about them. The beauty is that to access space, 4.35 miles per second is where the action really gets hot and heavy. At 4.35 miles per second, you can launch a 10-ton vehicle and get 33% fraction into LEO [low Earth orbit]. If you start with 11 tons, you're going to have 7275 pounds in LEO."

The success of the 10-ft. prototype



The SHARP firing sequence begins with the ignition of a methane gas mixture at one end of the steel pump tube. That explosion drives a 1-ton steel piston down the pump tube, which has been filled with pressurized hydrogen gas. The piston rapidly compresses the gas to 60,000 psi in the high-pressure section (below), destroying a coupling holding the projectile in the attached depressurized launch tube. The projectile is driven down the 4-in.-dia. tube at an extremely high speed and it bursts through a thin plastic sheet covering the end of the gun. All recoil forces are absorbed through the use of three sleds—two 100-ton sleds and one 10-ton sled—mounted on railroad tracks.



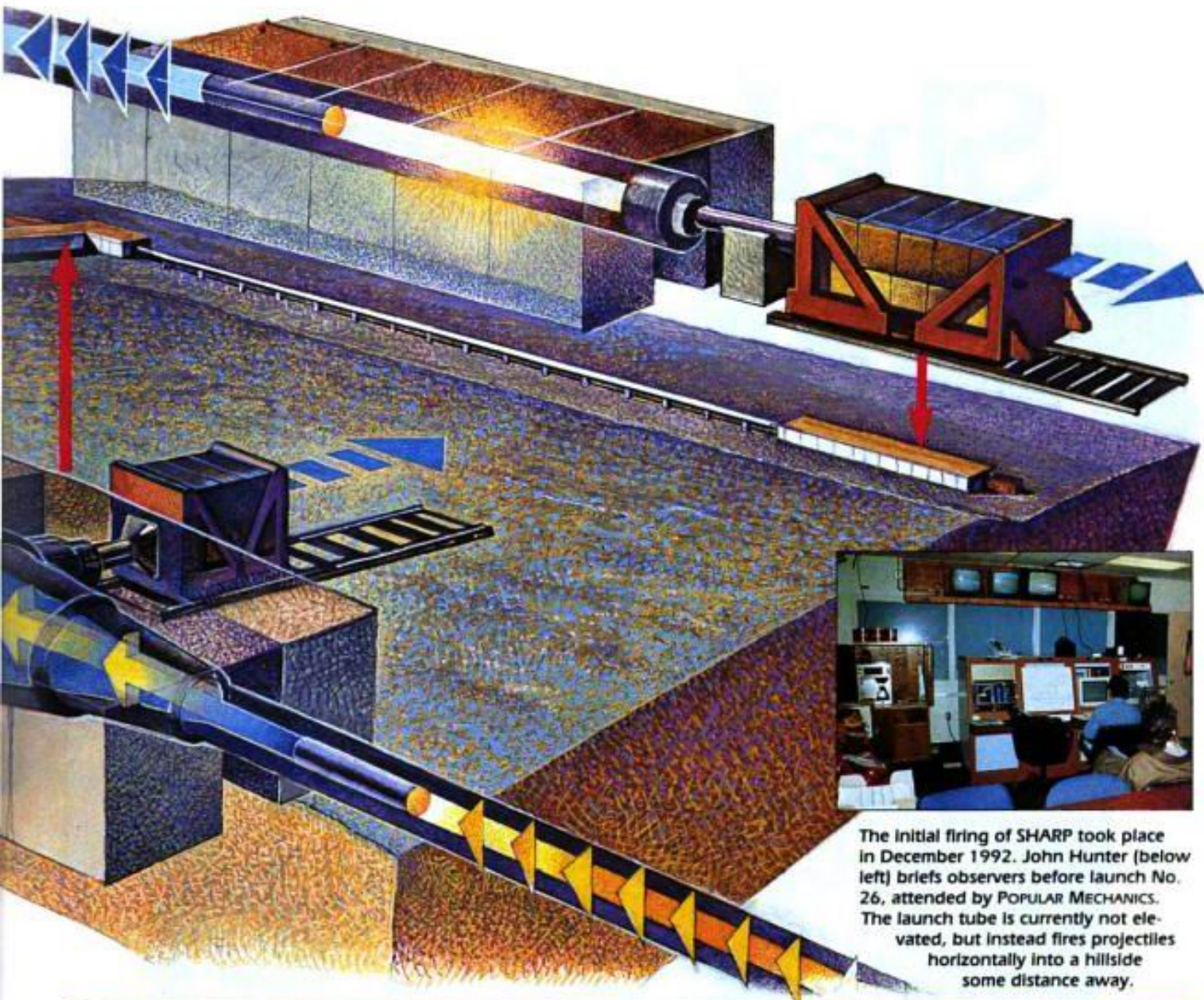
justified additional LLNL research and development funding for a "space gun" project identified as Super High Altitude Research Project, or SHARP. (Hunter chose the name in recognition of the U.S. government's HARP Super Gun project, which was conducted during the mid-1960s with standard powder technology.)

Located at LLNL Site 300, SHARP is the world's largest gas gun. The 425-ft.-long system was built in a unique L-shaped design with a 270-ft.-long combustion section and pump

tube mounted at a right angle to the 155-ft.-long launch tube. The original design was driven by a desire to minimize the height of any supporting gantry that would be required to elevate the tube for space launch.

"SHARP has only gotten to 1.92 miles per second because we're launching fairly big masses and we haven't jacked up the pressures very high," Hunter says. He adds that achieving the requisite 4.35 miles per second is "totally doable," based on both computer-model and lab-gun experience.

LINE PHOTO (LEFT) SCOTT GOURLEY PHOTO (TOP LEFT)



The initial firing of SHARP took place in December 1992. John Hunter (below left) briefs observers before launch No. 26, attended by *POPULAR MECHANICS*. The launch tube is currently not elevated, but instead fires projectiles horizontally into a hillside some distance away.



First, Hunter will build and fire a prototype system dubbed the "Micro Launcher." "Our Micro Launcher design is so small that you'll hardly see the projectile—maybe only 50 mils or one-twentieth of an inch," Hunter says. "That sounds crazy, right? I helped build the world's biggest gun," he says jokingly, clearly aware of the irony.

Hunter is also devoting considerable attention to the design of specially hardened satellite packages and has recruited experienced satellite designers for his team of engineers.

They will use the prototype systems to ensure satellite stability as it leaves the launch tube, as well as to address g-force hardening. The largest commercial guns will subject the satellites to 1000 g's for approximately 1 second. Although this is easily met by circuit designs, it may require hardening of components like solar cells or deployable antenna structures.

Based on SHARP experience, Hunter's engineers predict that the guns can easily be fired once per working day. Given a rate of 300

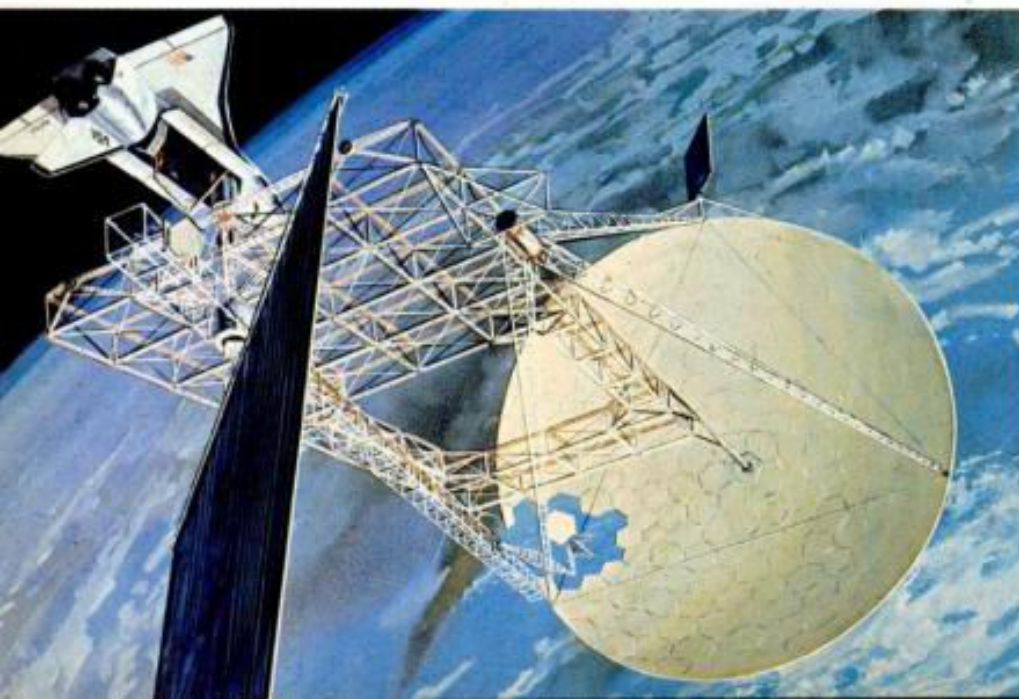
launches per year and a payload of 10,000 pounds per launch, the system has the potential of placing approximately 1500 tons a year into LEO. Moreover, at a target launch cost per pound of about one-twentieth of a modern rocket launch, the company estimates a breakeven point between the first 50 and 100 launches.

"The house odds wouldn't bet on us," Hunter says. "That's not a condemnation of house odds. That's just the way that the house works. But this is going to happen."

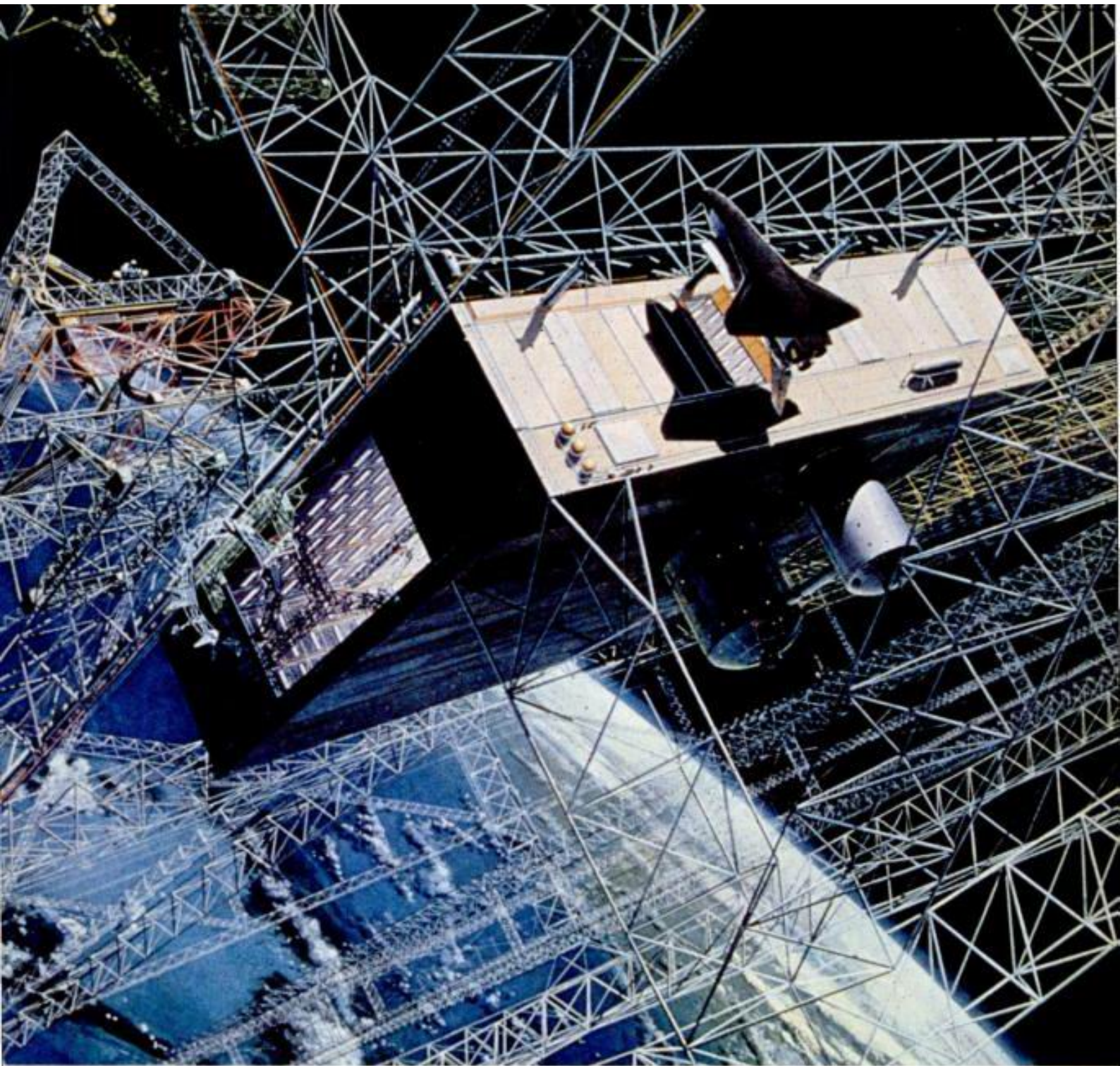
PM

Giant space structures

—how we'll build them



Cigar-shape space station (upper left) has equipment mounted on boom of space beams. Shuttle, docked to orbiting station, has ferried up replacement parts being installed by Grumman's remotely operated cherry picker at end of crane. Practice in such jobs is essential for building orbiting construction shacks (lower left). Here, Shuttle's remote manipulator arm lifts antenna sections onto a trolley that scoots them down to cherry picker for positioning. Large solar arrays power this equipment, which is fashioning the nucleus of a giant solar power station. When completed, miles of weblike trusses (above, right) would be covered with solar cells. In this Boeing version, the framework would be made of thin, telescoping struts brought up in the Shuttle. But both versions would convert solar-generated electricity to microwaves, beaming them—via a giant antenna—to an Earth station for re-conversion to electricity.



An alien environment demands unique building methods and materials

By JIM SCHEFTER

The night view to the south is spectacular. A slightly curved row of bright objects, 45 degrees up from the horizon, rivets the darkness. It looks like a glowing dotted line, waiting for some giant hand to tear open the sky.

Each dot is, in fact, a separate space station or power-generating satellite anchored in orbit 22,300 miles above the equator. So vast is the volume of space that dozens of stations can be set in that line with none affecting any other.

But don't look for that dotted line in the sky just yet. You'll only find it in a few artist's drawings—and in the imaginations of the engineers already at work to make it happen.

Some proposals now being studied involve putting 500 workers into orbit for months at a time to build platforms measured in kilometers. That kind of sky-high thinking—coming at a time when it's still a major chore to put five astronauts into space for a week—makes people shake their heads and wonder what those dreamers will think of next.

But the dreamers have a point. It's hard to fire the imagination of Congress, or of us taxpayers who foot the bill, with glowing descrip-

tions of trusses, beams, joints, and connectors. So the dreamers, practical engineers that they are, talk of mind-boggling satellite solar-power stations as in the painting above.

But they're doing more than dreaming and talking. I've just visited laboratories on both coasts, where NASA contractors are working on volleyball-size joints and beam components you can wrap around your fists. They're developing automatic machines that can spit out beams thousands of feet in length in the weightless conditions of space. They're also designing and testing joints and electrical sockets that will allow the deep-space construction crews to erect

Continued



Strut-making in space, the General Dynamics beam-making machine (top, inside NASA canister) extrudes beams made of a graphite-glass laminate. Model of Grumman's working beam former (left) sits upright in Shuttle. Yellow cartridges eject crosspieces for welding to the end caps. These are roll-formed from aluminum strips fed from the white reels.

Amazing new power from ocean depths

by Richard F. Dempewolff

Take warm water from the ocean's surface and cold water from its chilly depths and you have a "heat engine" capable of producing vast quantities of electrical power. Scientists have long known the principle, but until recently have lacked the means to put it into practice.

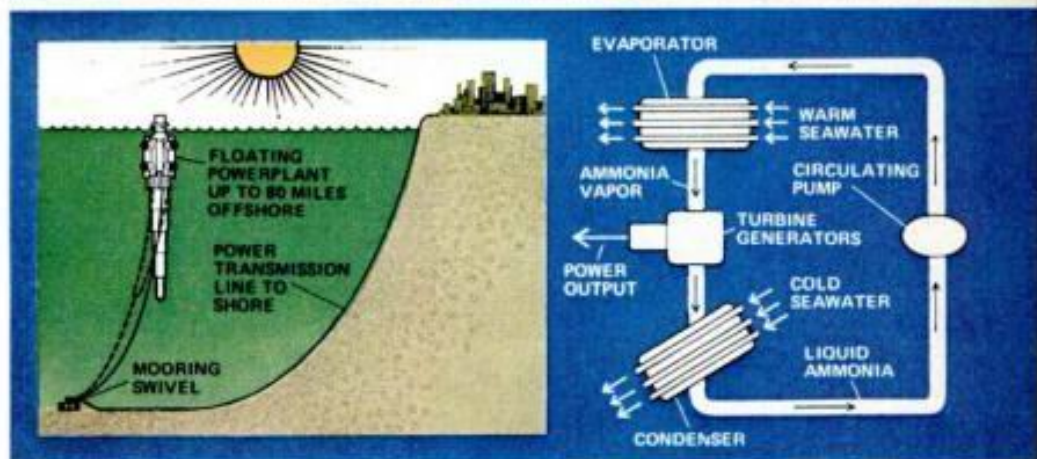
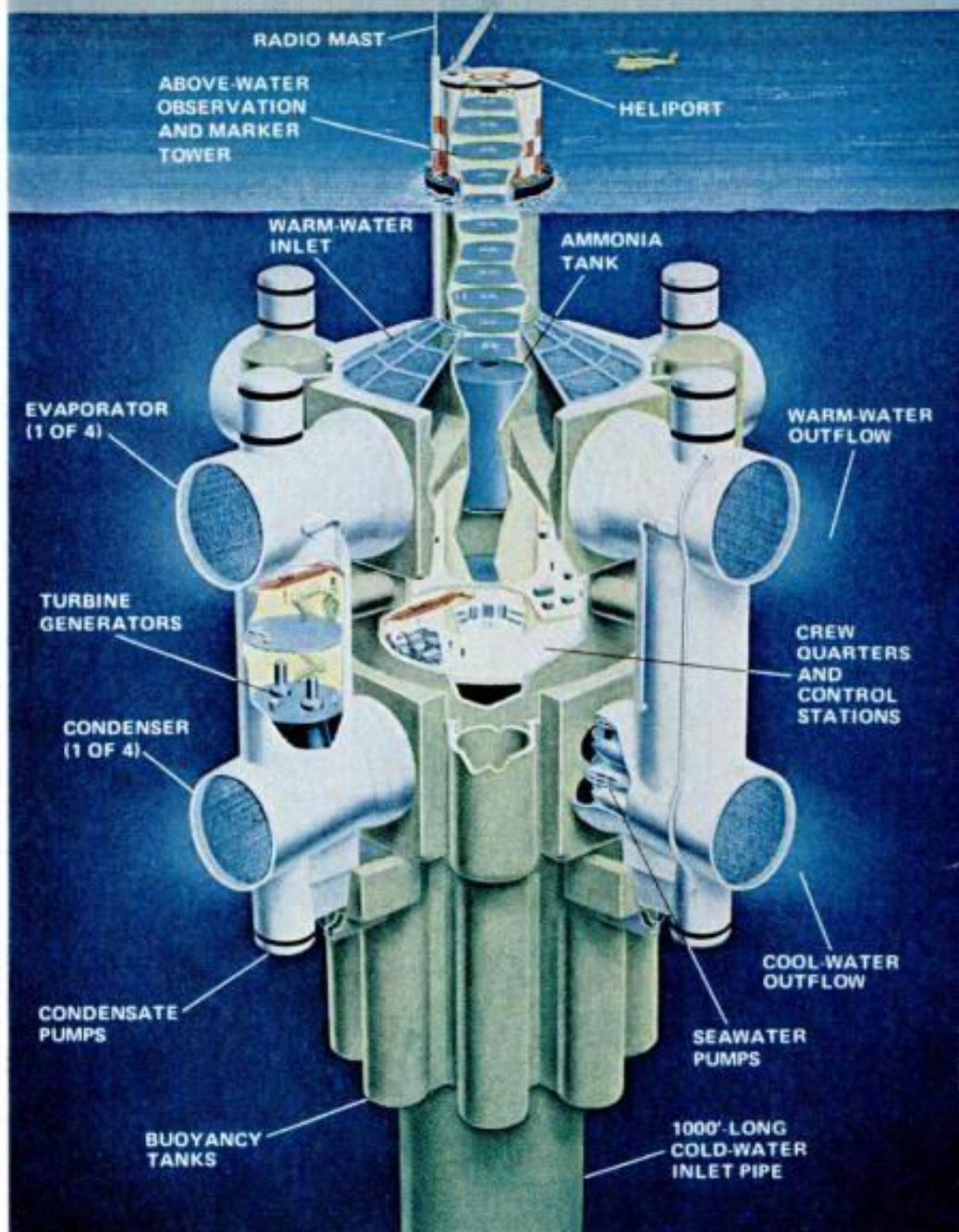
Now, under a federal program called OTEC—for Ocean Thermal Energy Conversion—are coming practical proposals for ocean-based powerplants whose "fuel" is merely a temperature differential in seawater. One of the most spectacular is a plan developed by Lockheed Missiles and Space Co., assisted by Bechtel Corp. and T. Y. Lin International.

Heated by the sun, the surface of the ocean runs 30° F. to 35° F. warmer than near-freezing waters farther down. This makes the sea a gigantic solar "storage battery" of thermal energy. Converting this energy into usable power requires turbines driven by a working fluid that vaporizes and condenses under relatively small changes in temperature—in this case, ammonia.

Pressure spins turbine

The ammonia is pumped through an evaporator warmed by surface water. Here it vaporizes, expands and its pressure spins turbine blades. The turbine, in turn, drives a generator that produces electricity. As the ammonia vapor leaves the turbine it passes through a condenser chilled by cold deep water. Here it condenses back into liquid form and is pumped around again to the evaporator in a continuing cycle, as shown in the diagram at lower right.

The process is basically simple—it's the equipment to make it work that becomes elaborate. The Lockheed design calls for an enormous floating factory—a huge tower-like structure, supported by buoyancy tanks, that rides almost fully submerged, like an iceberg. Some 250 feet in diameter, the monster extends more than 1500 feet deep. Sprouting from its sides are four self-contained



evaporator/condenser units, complete with power-generating turbines, circulating pumps and controls.

Warm surface water for the evaporators is scooped in at the top. Cold water for the condensers is drawn up from the bottom. Together the four power-generating modules produce 160 megawatts of electricity that can be piped up to 80 miles to

shore. Because the seagoing powerplant is submerged, it is unaffected by wind and waves. Tethered to a swivel mooring, it swings with the current, but can operate in hurricane-force storms. Best yet, unlike fossil and nuclear fuels, it wastes no vital resources, spews out no pollutants—indeed a promising answer to our mounting power crisis. ★★★

Cities in the sky

This month scientists will meet at Princeton University to work out plans for a fantastic scheme to put entire human colonies into orbiting space habitats—in possibly the next 20 years.

by Richard Dempewolf

Imagine a huge cylinder four miles in diameter and about 16 miles long orbiting in outer space. Inside, you step from your cozy little cottage, stroll down a flower-lined garden path, wander through bird-filled wildlands, picnic in a forest park, swim in a lake, fish in a river. Later, you hop on your bicycle or in your tiny electric car and run down the street to the shopping center for some groceries.

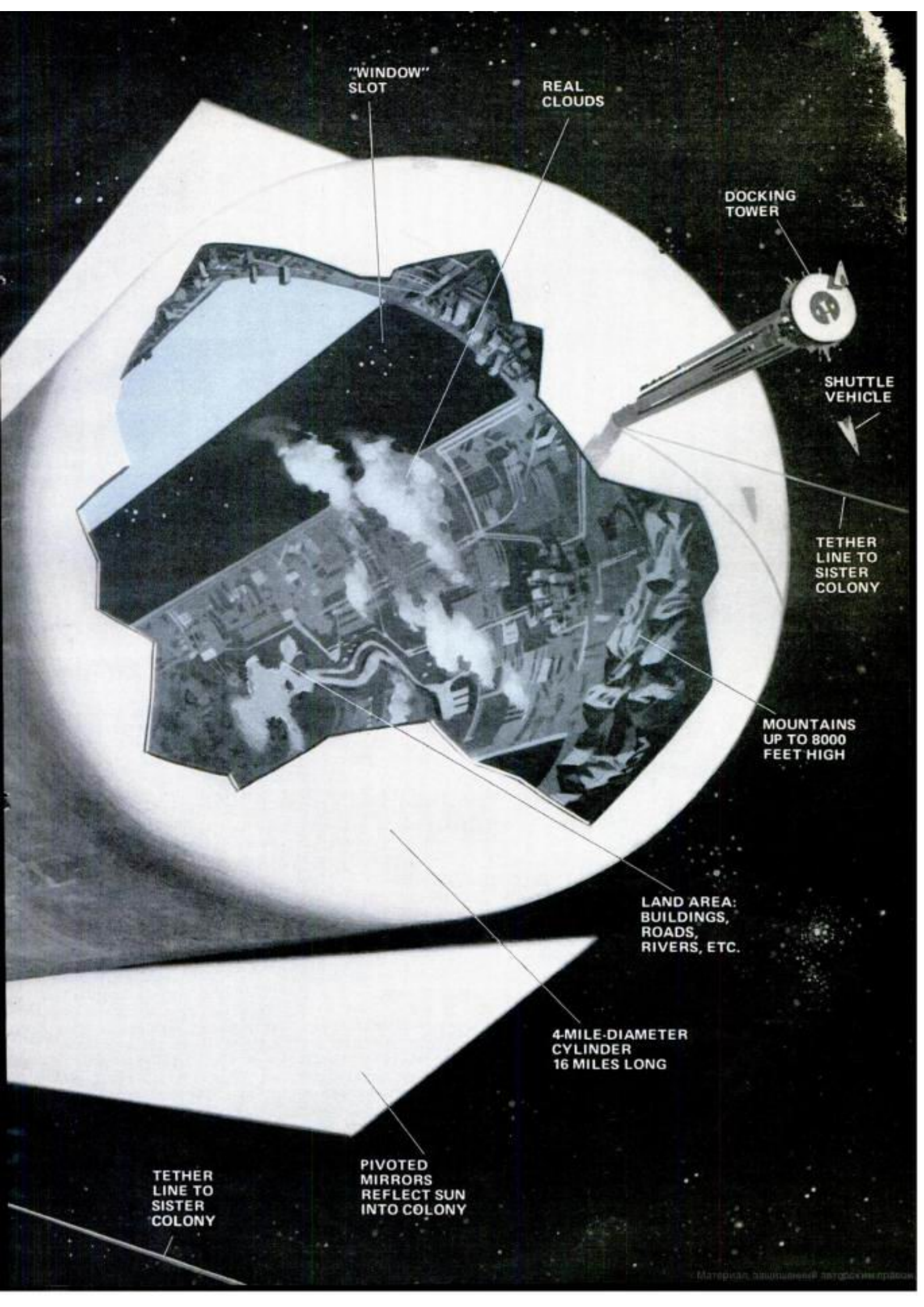
The cylinder will be rotating to produce artificial gravity, but you won't notice the motion. Everything will be just as it is on Earth—with a few pleasant exceptions. There will be no bustling crowds, no traffic jams, no blaring car horns, no ear-shattering sounds of heavy industry, no eye-smarting smog. The air will be clean and fresh and the climate perfectly controlled—except it may rain now and then for there are real clouds up in the “sky.”

If you like mountain climbing, you can scale peaks up to 8000 feet high and—oddly enough—your backpack will get lighter and the going easier the higher you go because the artificial gravity decreases as you approach the center of the cylinder. And if you want to soar like a bird, just launch your pedal-powered glider from a hillside and off you sail—the lessened gravity at the “higher” altitudes will make man-powered flight easily possible.

There will be other strange effects, too. As you look across the four-mile expanse of the cylinder's interior, your neighbors' homes will appear



Art: Roy Grinnell



"WINDOW"
SLOT

REAL
CLOUDS

DOCKING
TOWER

SHUTTLE
VEHICLE

TETHER
LINE TO
SISTER
COLONY

MOUNTAINS
UP TO 8000
FEET HIGH

LAND AREA:
BUILDINGS,
ROADS,
RIVERS, ETC.

4-MILE-DIAMETER
CYLINDER
16 MILES LONG

TETHER
LINE TO
SISTER
COLONY

PIVOTED
MIRRORS
REFLECT SUN
INTO COLONY

upside down on the "roof." Water will run uphill. If it decides to rain, it will rain in all directions—up and down at the same time. Up on those mountains there will be special trick "low-gravity" swimming pools where you can dive off a board and take several seconds before hitting the water. When you aren't swimming, you'll be able to bask on beaches and get a real suntan from real sunlight streaming in through long, portlike slots in the sides.

If all this sounds like science fiction, it isn't. You're living in a man-made mini-world—a bold new plan to put entire human colonies into space. Not just orbiting space stations filled with antiseptic lab gear, but actual full-scale reproductions of Earthlike communities complete with houses, schools, stores, hills and valleys, trees and streams, roads and wildlife.

The project is not only feasible; it is under serious study right now. This month some 100 prominent physicists, engineers, astronomers, space-flight experts and other scien-

otherwise dull calculations more interesting by applying them to a glamorous, if theoretical, project. "As sometimes happens in the hard sciences," he observes, "what began as a joke had to be taken seriously when the numbers began to come out right."

The numbers indicated that completely self-contained, self-supporting, highly livable man-made mini-worlds could, indeed, be constructed in space—using *only* materials and technologies that already exist!

The initial prototype colony, O'Neill suggests, would be a small one supporting about 10,000 people. From this would eventually come full-size space communities with populations of 400,000 circling the Earth. If a decision is reached to begin construction soon, O'Neill estimates the first colony could be completed by the late 1980s—though you probably won't be able to move right in. It will take several years, using electrical power from solar energy, to get the gigantic cylinders spinning at proper speed. In any case, space communities *could* be ready by about the end of the century—in time for your children to be among the first space settlers in history.

Assuming free use of the present body of technical knowledge, projected cost of the initial prototype colony is comparable to that of the Apollo project—about 33 billion 1972 dollars. Within a few years, however, products and power produced in space would pay for the cost of construction, thus making such colonies financially self-liquidating.

For our own Earth, the environmental and ecological effects of space colonization will be staggering. It will take the pressure off our current population explosion. It will lessen the drain on our rapidly dwindling natural resources. It will end famine and disease caused by overcrowding. It will eliminate industrial pollution of our air and waters because manufacturing and power-producing plants will be moved from Earth to special "clean" facilities in the sky as part of the space-colonization program.

If O'Neill's proposals are followed, here are some likely prospects for the future: By the late 1990s or early 2000s, there would be no need for the construction of additional power-generation plants on Earth. Solar power stations in orbit would beam energy to Earth by low-density microwave, avoiding any need for nuclear power. By 2015, a significant fraction of all humanity would be living in space colonies. The population on Earth might even begin to decline. A thriving economic inter-

change between Earth and space would be established. By 2050, many industries now polluting the Earth's biosphere would have been moved to space factories, using pollution-free technology. Waste would be recycled, employing the unlimited low-cost energy available in the colonies.

With its population stabilized and pollution eliminated, Earth could become the "Garden of Eden" of the solar system.

Meanwhile, life in space will be much like it is here, with regular, day and night cycles, natural sunlight, normal gravity and an Earth-



Princeton physicist Dr. Gerald K. O'Neill (right) explains his space colony plan to PM reporter Richard Dempewolff at left.



UNITS CONNECTED TO EACH OTHER AND MAIN BODY BY LIGHT CABLE

AGRICULTURAL, MANUFACTURING AND RESEARCH MODULES FORM 40-MILE-DIAMETER "HALO" AROUND END CAP OF MAIN COLONY

tists will meet at Princeton University to confer on realistic—not hypothetical—ways and means of implementing the plan. Organizer of the gathering and originator of the space-colony proposal is Dr. Gerald K. O'Neill, professor of physics at Princeton. O'Neill is a young, personable, dynamic, entirely hard-headed physicist who knows what he's about. "We can colonize space now," he says, "using 1970s technology. New techniques and approaches are needed, but knowledge and capability exist." He has data to prove it.

The space colony concept began as an "amusing" exercise for a group of ambitious physics students. The object, says the professor, was to make

like environment. All this will take place inside O'Neill's four-mile-diameter cylinders whirling around the Earth like satellite moons. The huge tubes will be pressurized to produce a "shirt-sleeve" atmosphere, and revolve to set up centrifugal forces simulating normal Earth gravity.

Actually, the cylinders will be arranged in pairs, tethered together by cables about 50 miles apart to insure precise orientation in space. The two tubes will counter-rotate, each canceling out any gyroscopic effect the other might produce, so the pair always remains pointed endwise toward the sun. The cylinders will each turn once every two minutes, powered by solar energy.

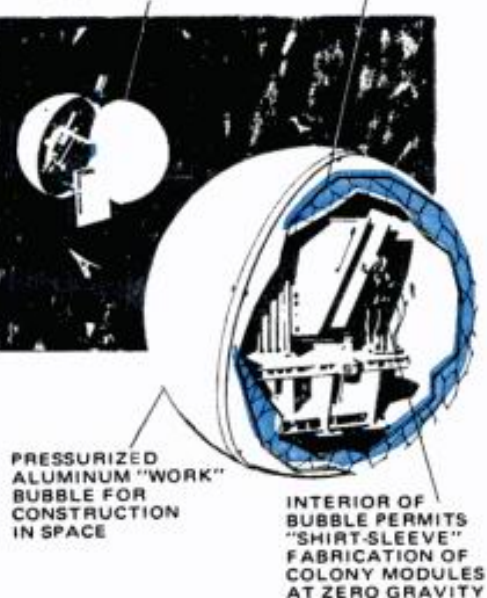
Outer walls of each cylinder will be divided into six longitudinal sections of alternating opaque and transparent material. The three opaque strips are "land" areas, built up with real rock and soil. Virtually any type of terrain can be simulated, from rolling Berkshire hills to sweeping western plains, a lush tropical paradise or lonely arid desert. Each land area is two miles wide by 16 miles long—big enough, O'Neill points out, to duplicate the south coast of Bermuda or the Carmel Bay area of California. In the prototype plan, an 8000-foot mountain profile copied from the Grand Tetons in

Wyoming is proposed as a surface for one cylinder end cap.

The alternating transparent panels, identical in size to the land strips, will admit sunlight. Three mammoth rectangular mirrors, hinged to open out above the transparent strips, will reflect the sun into interior land areas and make the sun visible to space dwellers just as it appears on Earth. By adjusting angles of the mirrors, it's possible to make the sun traverse the sky in an apparent dawn-to-dusk cycle and also to alter seasonal climates within the space colonies. You could even plan, suggests O'Neill, "a phase difference of seasons between the twin cylinders and have midwinter in one while it's midsummer in the other." Thus space colonists, visiting each other in small shuttle craft, could enjoy brief climate changes just as winter-bound Earthlings head south for a sunny retreat.

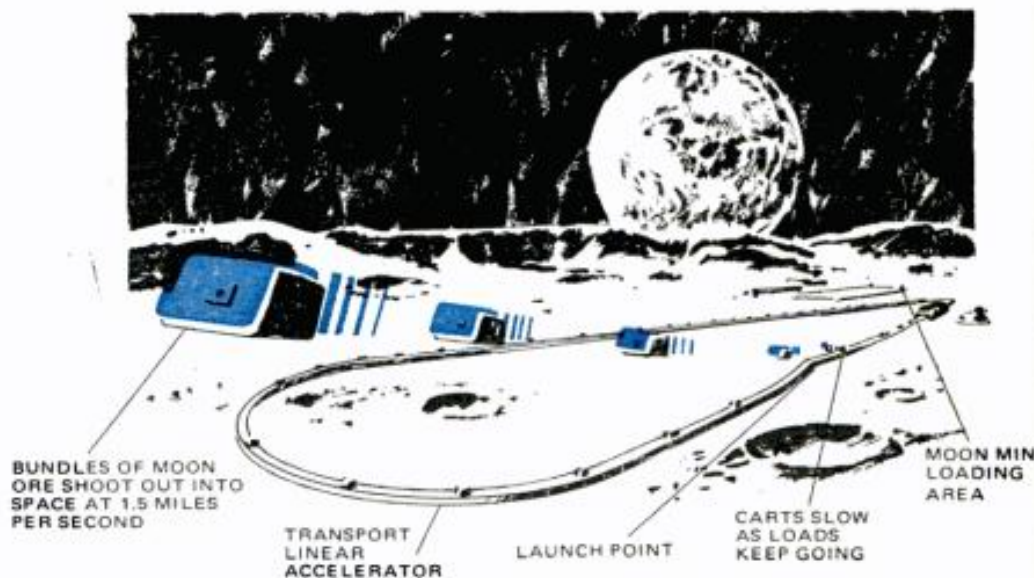
Almost nothing is impossible in the never-never storybook land of outer space. There is one problem, though—it's with stars. If you turn the mirrors away from the sun to reflect in the stars, the stars would appear to rotate every two minutes and "you'd get dizzy," O'Neill observes. But space dwellers will still get to see magnificent views of the

BUBBLE SEPARATES INTO TWO HALVES FOR REMOVAL OF EACH MODULE AS IT'S COMPLETED



stars from zero-gravity observatories and hotels just outside the habitat.

Crops will be grown outside the main cylinder in a "halo" of smaller cylinders or pods surrounding one end. The advantage of keeping agricultural areas outside, in addition to creating more living space inside, is that each one can be individually tailored to suit the specific things



you want to grow. According to Dr. Eric Hannah, O'Neill's right-hand man at Princeton, "In each of those outside cylinders you can change the climate and seasons to accommodate the crop. Each is a separate environment geared to citrus fruit, poultry, winter wheat, livestock—whatever you want."

Other external pods would be used to house industries, workshops, automated factories, scientific research labs, observatories and other special facilities. Thus all industrial, manufacturing and experimental work would be kept safely away from "civilization" in the main colony. As Hannah explains, "The external pods would be lashed in a space frame of light cable, probably, so they wouldn't run into each other. But basically they'd be independent units. That way, if there's a plant or animal disease, you can isolate the unit and sterilize it." Products produced in these external labs and factories could be sold to Earth, including some highly sophisticated things that are actually easier to make in space such as special crystals, supermagnets and other high-vacuum items. Power from satellite stations could also be sold to Earth.

The space colonies will circle the Earth along the same orbital path as the moon. The reason is curious. It has long been known there are five orbiting points in space where the gravitational forces of Earth and moon balance out. Any object stationed within one of these vast, roughly spherical gravity-less "pockets" would tend to be trapped there, orbiting Earth forever without need for propulsion.

These five gravity-free points, known as "libration centers," are designated "L1" through "L5". Areas L4 and L5 follow the same orbit as the moon—L4 ahead of it and L5 following it. Of the five centers, only

L4 and L5 are stable so these have been chosen as locations for the space colonies. The twin-cylinder space habitats would be strung out along these orbital paths at 120-mile intervals—far enough apart to be safely separated, yet close enough for easy access to each other. For intercolony travel, there would be public space shuttle "buses" making regular trips between habitats. To visit your nearer neighbors in your twin colony, you'd hop into an engineless, pilotless craft that can "unlock" from the outer surface of the revolving habitat at a preprogrammed instant and be flipped into space by centrifugal force at about 400 mph. In nine minutes, you'd "lock" onto the spinning adjacent cylinder at zero relative velocity. Docking towers and spaceports are at the "nose" of each cylinder to handle such craft, also space flights from Earth.

Most fantastic of all, perhaps, is the fact that these colossal colonies will not only be built in space, but will largely use material and energy sources found in space. Except for certain materials and special construction machinery needed initially to get the program started, only about two percent of all supplies will come from Earth, predicts O'Neill. Ore from the moon and asteroids, for instance, will be used extensively in fabricating parts of the habitats—at a fraction of the cost of moving the same materials from Earth. "To bring a kilogram of material from the moon to L5," says O'Neill, "takes less than five percent of the energy needed to move it from Earth."

To transport moon ore to construction sites in space, a unique device has been proposed. It takes advantage of the moon's vacuum and low escape velocity—less than a quarter of what would be required to boost comparable loads from Earth. This ma-

(Please turn to page 205)

From Florida to Cape Cod— Without Moving

Hitchhiking a ride on the Gulf Stream, Dr. Jacques Piccard will turn off the motors of his unique submarine and drift on an amazing underwater voyage.

By WALLACE CLOUD

WHEN I CLIMBED UP THE SLOPING DECK of the submarine from a rubber boat, she was in the last stages of fitting out at West Palm Beach. (It seems awkward to call a sub named *Ben Franklin* "she," but there's no way around it.) By now test dives have taken place, and soon she'll be towed out to sea, with Jacques Piccard, a Grumman skipper, and Navy scientists aboard. The *Franklin* will sink and remain submerged for a month or more, slowly drifting some 1500 miles up the Gulf Stream like an undersea *Kon-Tiki*.

Throughout the voyage, Dr. Piccard told me, the sub may remain in the same cubic mile of seawater as it moves from Florida to the vicinity of Cape Cod. In the

Artist's concept of the *Ben Franklin* as it leaves the Blake Plateau (background) and begins descent to 2000 feet. Band of light blue is deep-scattering layer of plankton (shrimp and small fish) around which tuna swim. Strippers feed at the edge of the Plateau and giant sea squid lurk in the depths.

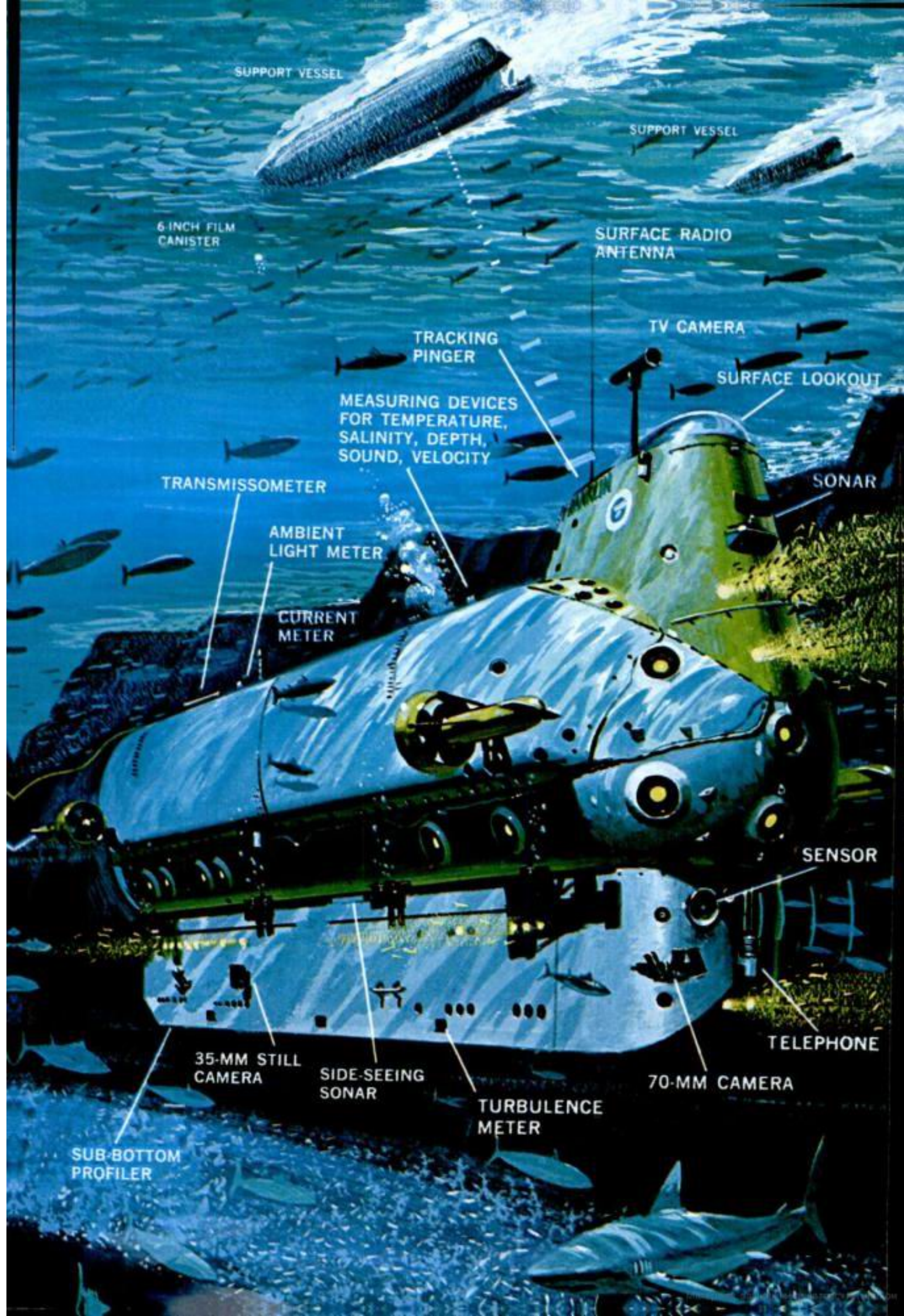
BEN FRANKLIN IN PREVIOUS POSITIONS

BLAKE PLATEAU

MAGNETOMETER

PROPULSION
MOTOR

Illustration created exclusively for Popular Mechanics by renowned oceanographic artist, Ed Valigursky



SUPPORT VESSEL

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6 INCH FILM
CANISTER

SURFACE RADIO
ANTENNA

TRACKING
FINGER

TV CAMERA

SURFACE LOOKOUT

MEASURING DEVICES
FOR TEMPERATURE,
SALINITY, DEPTH,
SOUND, VELOCITY

SONAR

TRANSMISSOMETER

AMBIENT
LIGHT METER

CURRENT
METER

SENSOR

TELEPHONE

70-MM CAMERA

TURBULENCE
METER

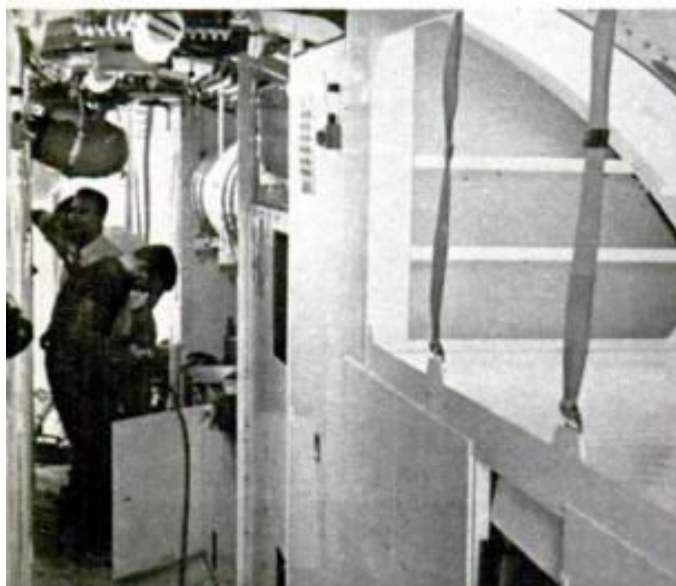
SIDE-SEEING
SONAR

35-MM STILL
CAMERA

SUB-BOTTOM
PROFILER



DR. JACQUES PICCARD, designer of the *Trieste*, in conning tower of the *Franklin* at port of Palm Beach



ENGINEERS CHECK WIRING in control area of the *Franklin* prior to test dives. Wardroom is beyond



gloom 300 to 2000 feet below the surface, the six men aboard will get to know that volume of water intimately. They will monitor its changes in temperature, observe the intrusion and diffusion of surrounding water, and watch the marine creatures that enter and leave their moving cell of fluid. In a submarine that floats soundlessly at any depth down to 2000 feet, they will become a part of the Gulf Stream, that river in the sea that carries 22 times as much water as all the land rivers of the world. Under tons of pressure, they must trust the Gulf Stream to take them for a ride; they will trust their vessel, designed by Grumman Aircraft Engineering Corp. and Dr. Piccard, to bring them safely through it.

A man of enormous drive, Piccard has already been to the deepest spot in the ocean, the bottom of the Marianas Trench, 35,800 feet down in the Pacific. He went there for the U.S. Navy in the bathyscaphe *Trieste*, which he designed with his father, Prof. Auguste Piccard, the famous stratosphere balloonist.

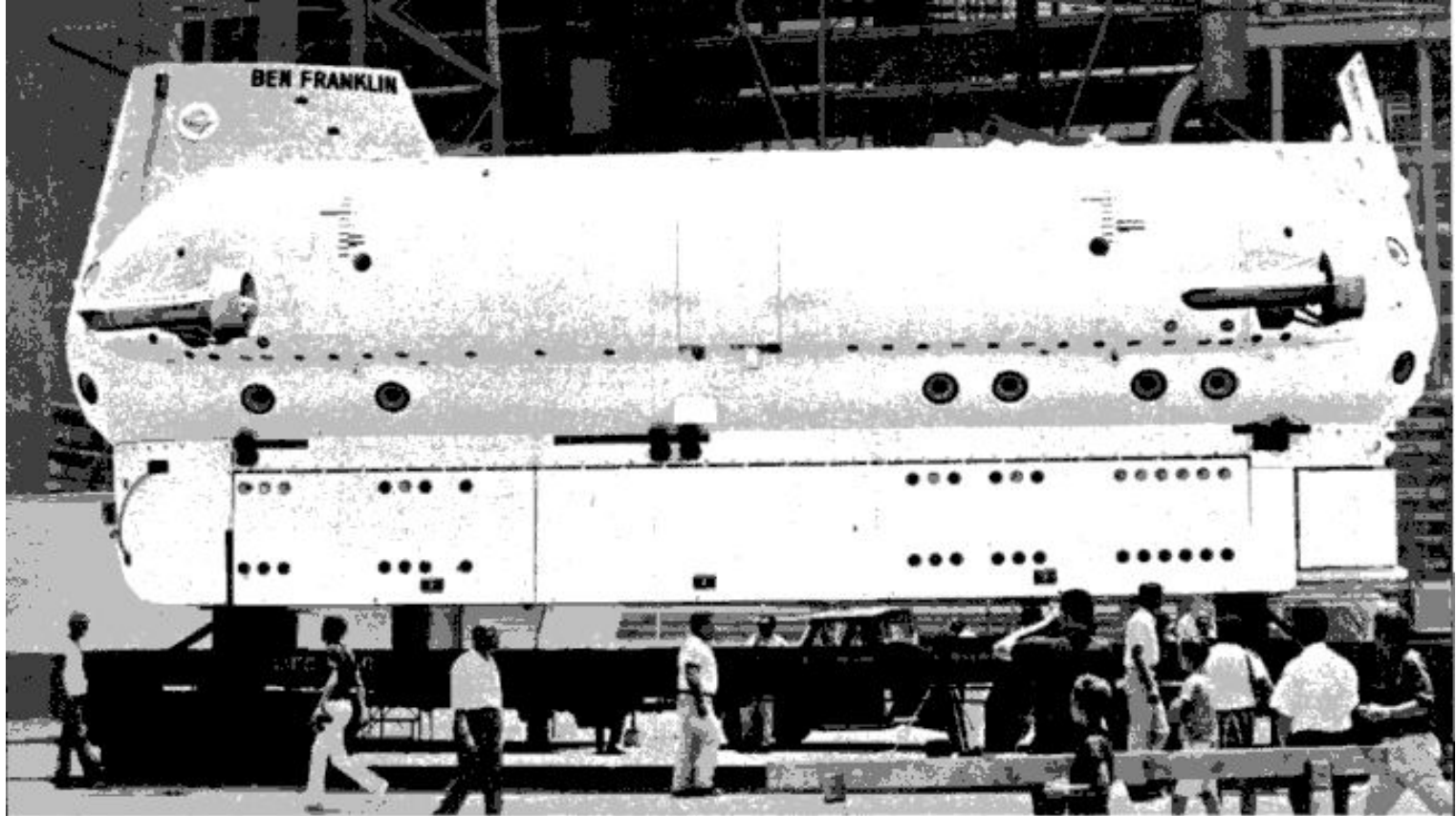
Before christening, the *Ben Franklin* was designated PX-15—the 15th Piccard experimental design. The numbers start from the world's first bathyscaphe, FNRS-3, which the Piccards built for the French Navy. *Trieste* was their next bathyscaphe. Another vessel, the *Auguste Piccard*, built in 1963, carried 30,000 sightseers into the depths of Lake Geneva.

In September, 1964, Piccard announced plans for the Gulf Stream drift. He didn't know where the funds might come from—but then along came Grumman Aircraft Engineering Corp. Construction of the PX-15 began in March, 1967, at Monthey, Switzerland. Grumman has spent \$2.5 million on the project so far, owns the *Ben Franklin*, and employs Piccard as a full-time consultant.

The Naval Oceanographic Office, which is participating in the Gulf Stream mission, is the first "customer"

VACUUM-JACKETED TANKS (left) will hold water (to prepare freeze-dried food) at 210° F. for month

POPULAR MECHANICS



BEN FRANKLIN is simple in basic design. Hull is 10 feet in diameter and capped with hemispherical ends. Length overall is 48 feet 9 inches. Four swiveling 25-hp electric motors jut from the hull, two at each end

to use the *Franklin*—a “mesoscaphe” or submarine designed for middle depths. Her maximum cruising depth is 2000 feet.

When I visited the sub at Palm Beach, engineers were busy making sure the boat will do everything required of her. Mooring lines held the yellow-and-white sub well out from the concrete bulkheads of her slip. She rolled a surprising amount, and that was the simplest way to avoid damage to the fiberglass ballast tanks and the motors, which project at the sides, said her skipper, Don Kazimir, a former Navy submariner.

The *Ben Franklin*, although a highly sophisticated research vessel, is surprisingly simple in design. Her pressure hull is a cylinder 10 feet in diameter, stiffened with 16 rings inside and capped with hemispherical ends, all welded of 1 $\frac{3}{8}$ -inch high-strength steel. Total length is 48 feet 9 inches. Slung beneath the hull is a “keel” consisting mainly of 26 tons of lead-acid storage batteries in an aluminum framework. Above the hull is a narrow metal deck, with a small conning tower forward. Bulging below the sides of the deck

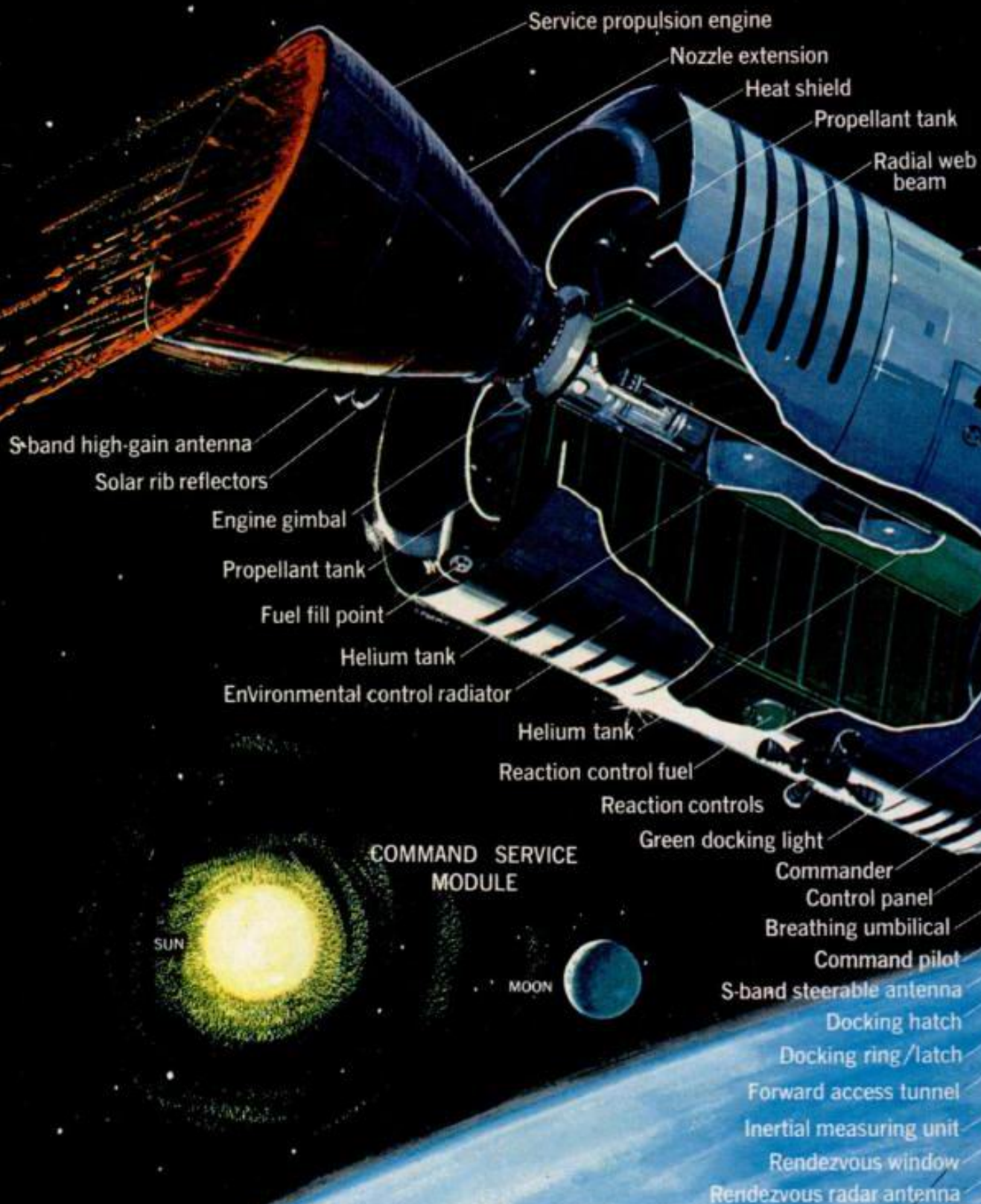
are ballast tanks. Four swiveling 25-hp electric motors jut from the sides of the hull at each end.

Inside, the sub was like a long corridor lined with bunks, workbenches and electrical gear. A portable air conditioner on the dock was blowing cold air into the forward hatch. Florida sunshine penetrated the clear water outside to pour through the three-inch-thick plexiglass windows in the ends of the hull (there are 29 viewports in all). Kazimir said a community of barnacles had already adopted the *Franklin*, some living comfortably on antifouling paint around the portholes. With no way to get out and wipe the windows, it's a question how good visibility will be by the end of the trip.

In the cockpit, engineers were checking out motor controls and power circuits. Divers beneath the hull were spotting faulty electrical connectors which had to be replaced before test dives could begin. Using electrical equipment in saltwater is the biggest operational difficulty facing the crew, Piccard told me.

Going through the hatch, I noticed a

(Please turn to page 212)



Command Service Module emerges from shroud using vernier rockets



CSM turns around to nose in toward Lunar Module



CSM mates with LEM



and both move away from third stage booster

With LEM attached, CSM uses main rocket



to move into proper orbit

APOLLO SPACECRAFT

Astronauts in first transfer from Command Module to Lunar Module in test flight while in Earth orbit.



VHF omni antenna

Fly away umbilical

Red docking light

Command module, service module fairing

Electrical-power
system radiator

Aft heat shield

Yaw motor

Side window

Crew access hatch

Rendezvous
window

LUNAR MODULE
(Ascent Stage)

VHF inflight antenna

Aft equipment bay

Reaction control thrusters

Docking guide

Oxidizer tank

Helium tank

Environmental controls

Fuel tank

Ascent engine

Radioisotope
thermal
generators

Scientific
equipment

LM pilot

Visual lunar
landing grid

S-band
antenna

Reaction control
thrusters

Ingress-egress
hatch

Platform and railing

LUNAR MODULE
(Descent Stage)

Specimen return box

S-band erectable antenna

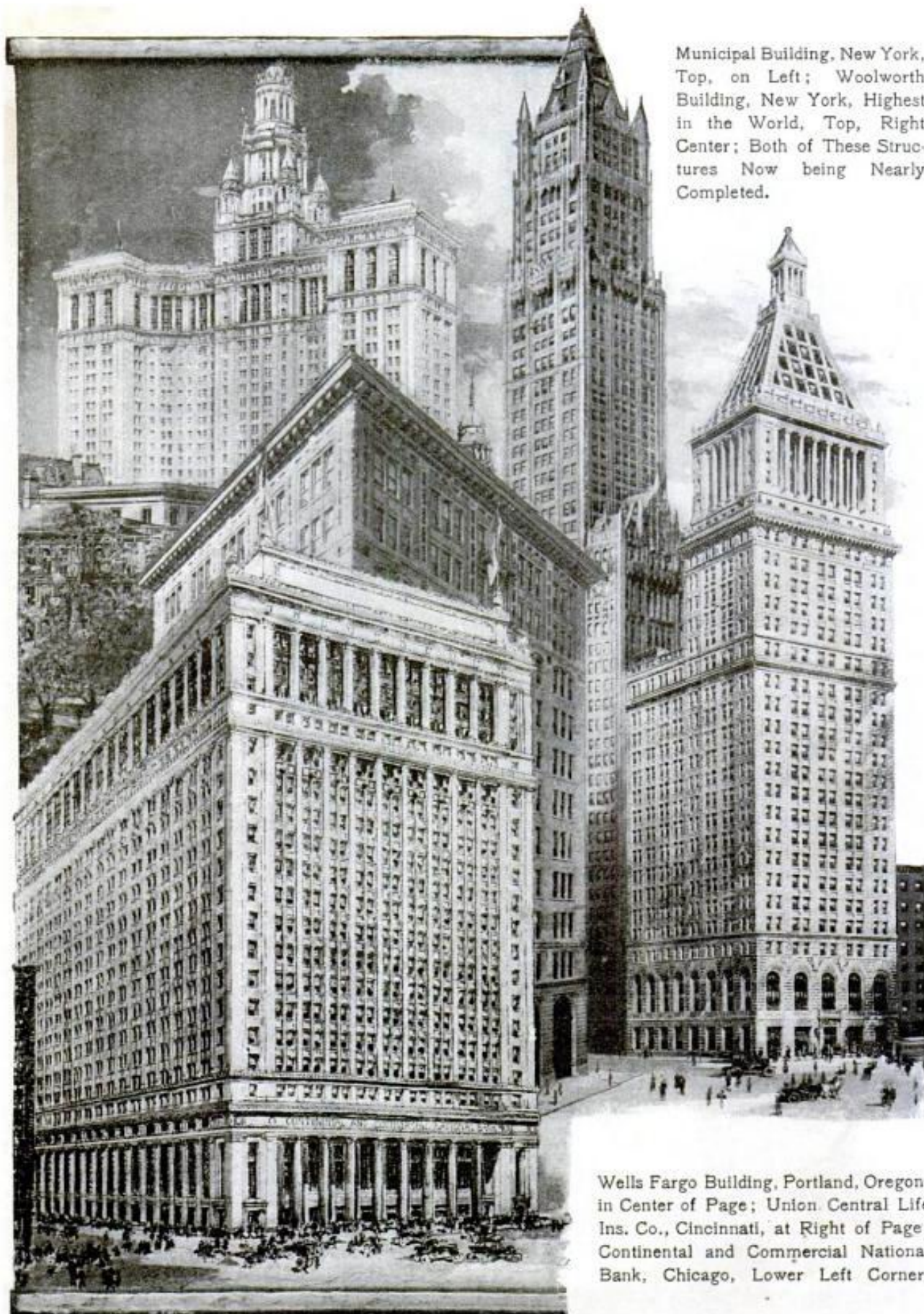
Descent ladder

Primary strut

Landing pad

Descent
engine skirt

Illustration created especially for Popular Mechanics by Fred Wertz, Ed Valigursky and Marian Manfredi



Municipal Building, New York, Top, on Left; Woolworth Building, New York, Highest in the World, Top, Right Center; Both of These Structures Now being Nearly Completed.

Wells Fargo Building, Portland, Oregon, in Center of Page; Union Central Life Ins. Co., Cincinnati, at Right of Page; Continental and Commercial National Bank, Chicago, Lower Left Corner.

L. C. Smith Building, Seattle,
Tower Building at Top of
Page; Whitney National Bank
Building, New Orleans, Top at
Right Center; Hoge Building,
Seattle, Upper of Two Build-
ings on Right.

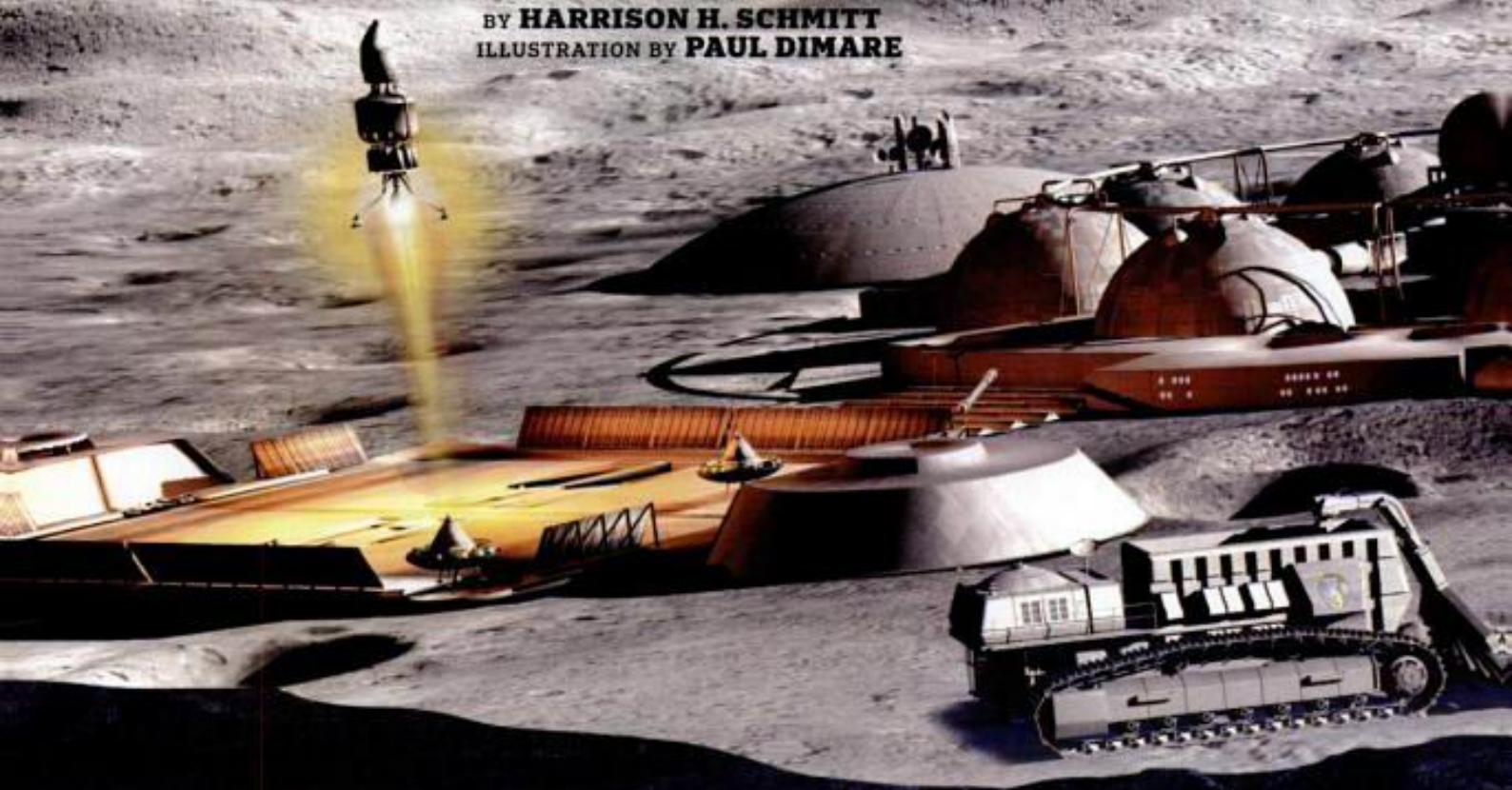


Maryland Casualty Company Building,
Baltimore, on Left; Front View of
Whitney National Bank, New Orleans,
Lower Center; Woodmen of the World
Building, Omaha, Lower Right Corner.

Mining The Moon

An Apollo astronaut argues that with its vast stores of nonpolluting nuclear fuel, our lunar neighbor holds the key to Earth's future.

BY **HARRISON H. SCHMITT**
ILLUSTRATION BY **PAUL DIMARE**



Apollo 17 astronaut Harrison Schmitt left the moon 32 years ago with 244 pounds of rocks and an abiding desire to see humankind continue its exploration of space. Now, in an exclusive essay for **POPULAR MECHANICS, Schmitt explains why the time is right for America to return.**



FUTURE MINERS: Robotic equipment would scrape and refine lunar soil. Helium-3 would be sent to Earth aboard a future space shuttle or perhaps be shot from an electric rail gun.

Living Off The Land

Exploration of the solar system will be fueled by materials found scattered across asteroids, moons and planets.

Moon

The discovery of a helium isotope, helium-3, on the moon has given scientists ideas on how to produce electricity far more efficiently than with hydrocarbons or current nuclear plants. The large amounts of energy would come without danger of releasing radioactive substances into the atmosphere.

Mining the lunar surface would not be cheap; the investment would be comparable to building a major transcontinental pipeline.



Mars

Studies conducted by NASA and others have determined that water, rocket propellant and chemicals needed to sustain a human outpost could be manufactured from martian soil and ice caps (right). Future astronauts might set up production plants that expand as others arrive. Eventually, the Mars base could become a resupply base.



Asteroid belt

Moon

Earth

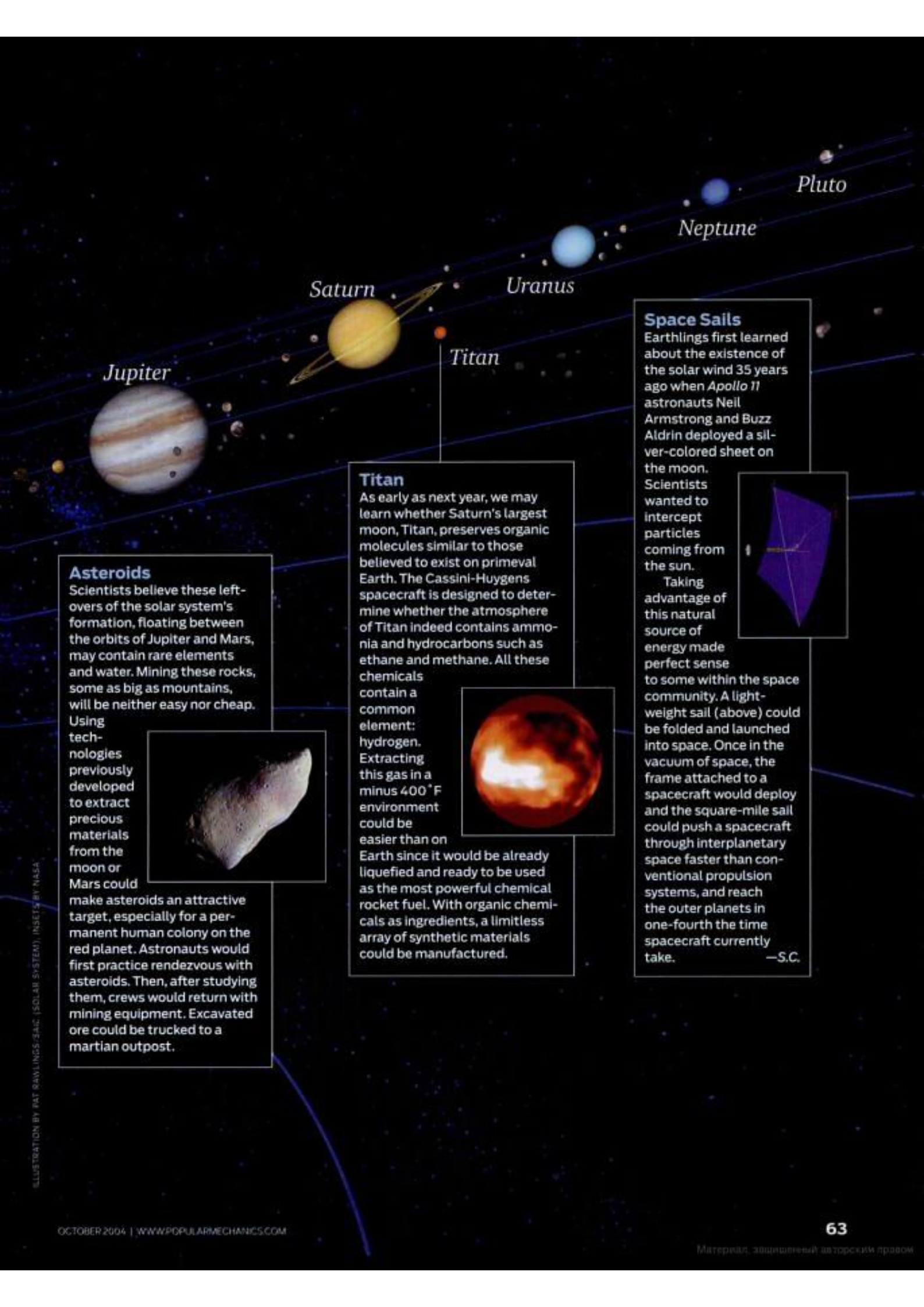
Mars

Venus

Mercury

Sun

*Solar flare
generating
solar wind*



Jupiter

Saturn

Titan

Uranus

Neptune

Pluto

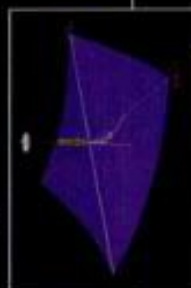
Space Sails

Earthlings first learned about the existence of the solar wind 35 years ago when *Apollo 11* astronauts Neil Armstrong and Buzz Aldrin deployed a silver-colored sheet on the moon.

Scientists wanted to intercept particles coming from the sun.

Taking advantage of this natural source of energy made perfect sense to some within the space community. A lightweight sail (above) could be folded and launched into space. Once in the vacuum of space, the frame attached to a spacecraft would deploy and the square-mile sail could push a spacecraft through interplanetary space faster than conventional propulsion systems, and reach the outer planets in one-fourth the time spacecraft currently take.

—S.C.



Asteroids

Scientists believe these leftovers of the solar system's formation, floating between the orbits of Jupiter and Mars, may contain rare elements and water. Mining these rocks, some as big as mountains, will be neither easy nor cheap.

Using technologies previously developed to extract precious materials from the moon or Mars could

make asteroids an attractive target, especially for a permanent human colony on the red planet. Astronauts would first practice rendezvous with asteroids. Then, after studying them, crews would return with mining equipment. Excavated ore could be trucked to a martian outpost.



Titan

As early as next year, we may learn whether Saturn's largest moon, Titan, preserves organic molecules similar to those believed to exist on primeval Earth. The Cassini-Huygens spacecraft is designed to determine whether the atmosphere of Titan indeed contains ammonia and hydrocarbons such as ethane and methane. All these chemicals contain a common element: hydrogen. Extracting this gas in a minus 400 °F environment could be easier than on Earth since it would be already liquefied and ready to be used as the most powerful chemical rocket fuel. With organic chemicals as ingredients, a limitless array of synthetic materials could be manufactured.



AIR POWER

Now emerging from the nation's top-secret drawing boards, a new generation of advanced-technology aircraft combining speed, stealth and versatility.

BY TIM COLE, Science/Technology/Aerospace Editor,
and JOSH EPPINGER;
PM Illustrations by Attila Hejja



The Advanced Technology Bomber
—with vectored thrust, radar-absorbing
materials and a low silhouette—
penetrates enemy airspace at Mach 1.

© Attila Hejja '87

FAST. Low. Virtually invisible.
Deadly.

The words describe the Advanced Technology Bomber, a crucial leg in America's nuclear triad that will join the Strategic Air Command in the mid-1990s. Incorporating "low-observable" stealth technologies, fly-by-wire controls and an astonishing array of electronic countermeasures, ATB also represents the pinnacle of aviation achievement as the turbulent 20th

century draws to a close. Similar technologies designed for light weight, high strength, increased range and payload, accuracy, survivability and maintainability are finding their way into a broad range of currently emerging aircraft. The latest developments include YF-22A, the Advanced Tactical Fighter and an entire family of advanced rotorcraft. The V-22 Osprey, scheduled to take flight in 1991, will be the military's airborne workhorse. Other high-tech

VERTOLs on the drawing board include LHX, the next generation light scout attack helicopter, designed to counter a rapidly expanding East Bloc armor threat; and X-Wing, the rotorcraft that will fly "map-of-the-Earth" at 30 knots to support ground forces, then accelerate to high subsonic speeds to engage enemy fighters.

Each is designed to perform a highly specific function on tomorrow's battlefields. They represent enormous prob-

2000



lems—and amazing possibilities—in the dynamic world of aviation technology.

Advanced Technology Bomber

We begin with the biggest—and clearly most secret—airplane construction project in American history. To fulfill the Air Force's requirement for a "long-range bomber that incorporates low-observable technologies," Northrop Corp. was awarded a \$36.6 billion contract (in 1981 dollars) to produce 132 Advanced Technology Bombers. These will complement the 100 Rockwell International B-1B bombers currently joining the Strategic Air Command.

Preliminary visions of ATB focused on Northrop's post-WWII YB-49 flying wing, an airframe that lacked severe surface angles and was thus considered difficult to track with radar. However, known control difficulties with flying wings—and a thickened, drag-inducing wing cross-section to accommodate payload—has most likely eliminated the concept from consideration.

Instead, numerous industry experts interviewed by POPULAR MECHANICS foresee a large conventional aircraft with a small cross-section in profile and nose-on. A blended shape between the fuselage and the slightly down-sloping wings will eliminate the hard intersections that bounce radar signals. A smooth, hard "chine" will flow from the forward wing-fuselage intersection

around the nose of the aircraft to provide additional nonintrusive sculpting, much like the shape of the forward fuselage of the SR-71 "Blackbird," America's high-flying reconnaissance plane.

Thrust vectoring through 2-dimensional exhaust nozzles will play a major role in control and stability, eliminating the highly observable vertical control surfaces in the tail. A refrigerant will be pumped through the exhaust outlets to reduce the aircraft's thermal signature. Positioning the engines—most likely improved versions of the General Electric F-101 currently serving in the B-1B—deep inside the airframe will further limit thermal detection. Early speculation placed the ATB's four engine inlets—hard, angular surfaces that are difficult to mask from radar—on top of the fuselage.

However, it's felt that placing inlets anywhere but on the bottom of the airplane will lead to air starvation at high pitch angles and during tight terrain-following maneuvers. Accordingly, air intakes will be placed on the underside of the fuselage. But they will open and close through a variable geometry system. High-speed flight will force more air into the intakes, thus requiring a smaller, less visible, aperture. The aperture will increase in size during slower flight over friendly territory.

The resulting shape of ATB will have a radar cross-section one-half that of the B-1B, which in turn has a radar cross-section $\frac{1}{100}$ th that of the aging B-52. And like the B-1B, ATB's objective will be to fly at high subsonic speeds under an enemy's radar and fighter umbrella to strike targets with extreme accuracy. A chief bombing objective might be rail-based ICBMs that change their launch position frequently. Satellites will detect the movement of these mis-

siles and transmit their locations to the national command authority, which will send coded target information to the ATB enroute. The ATB crew can change their flight plan or return to base if requested to stand down—a flexible response not afforded by cruise or intercontinental ballistic missiles.

To carry out its mission, it's conceivable the Air Force will reduce the ATB's flight crew to three from the B-1B's current four. A pilot/copilot will manage the flight from the forward cockpit. An offensive/defensive weapons systems officer will monitor enemy threats, jam enemy sensors, release expendable countermeasures in the form of chaff or flares and drop ordnance. The copilot and weapons systems officer would share some of the work of delivering the load in this scenario.

With an ultralow radar cross-section, the Air Force could afford to create a larger aircraft capable of carrying up to 125,000 pounds of ordnance in multiple stores bays internally. The B-1B currently holds 75,000 pounds inside, and a potential for 50,000 pounds of cruise missiles or other weapons on external hardpoints. The payloads are awesome compared to the 4000-pound bomb loads carried by the B-17. Fewer crew and a correspondingly smaller crew compartment will mean more room for electronic countermeasures, actual weapons and fuel. Unrefueled range will increase well beyond the B-1B's current 6100 nautical miles—a 15-percent increase to 8580 nautical miles has been discussed. Bomb loads will consist of a follow-on generation of the Mark 82 gravity bomb, short-range attack missile, long-range advanced cruise missile, and, potentially, antiradiation cruise missiles that can knock out enemy targeting installations in advance of a strike.

Key features of ATB will be the latest



advancements in radar absorbing materials (RAM) that absorb microwave energy; materials like high-tensile-strength reinforced carbon-carbon, thermoplastics and ferromagnetics. The paint surface, too, will be of a radar-ablative substance. Pyramid- or cone-shaped shells lined with ferrites and positioned just under the leading edge of the wings and fuselage will capture and absorb radar energy.

In short, the ATB fleet will be a potent and formidable component in America's nuclear arsenal. While optimistic progress reports continue to emanate from Northrop Corp., it's highly doubtful the Air Force will be able to conduct the first flight of ATB in late 1987 as originally scheduled. A flying proof-of-concept aircraft in late '88 or early '89 is more realistic, according to Air Force insiders.

The Advanced Tactical Fighter

The Air Force colonel is like John Madden diagramming a delayed draw.

"The Soviets have been gradually increasing their fighter force with a look-down, shoot-down capability," he explains. "So in response to this threat, I need an aircraft to cross over and take them on, to engage them. Therein lies the requirement for the Advanced Tactical Fighter."

The speaker is Col. James Fain Jr., director of the Advanced Tactical Fighter (ATF) system at Wright-Patterson Air Force Base outside Dayton,

ATF will include a smart cockpit, "low-observable" technology and canard-induced "super-maneuverability." A proposed 3-D threat indicator "floats" in an ATF concept cockpit (below).



Ohio. "If we don't respond to the threat, we lose the capability to conduct air combat maneuvers. In short, we lose air superiority. And that's the thing we can't tolerate. We've learned that in war after war. We must have air superiority or we don't have a chance."

Northrop, partnered with McDonnell Douglas, and Lockheed, its Los Angeles-area rival, teamed up with Boeing and General Dynamics, are currently going nose to nose to develop two prototype ATFs over the next 41 months. The contracts are worth \$691 million each, and defense industry executives are calling it "one of the bloodiest competitions in the history of the aircraft business." The winner will waltz away with a production contract that calls for 72 aircraft a year, at least to the year 2005, or until 750 of the ATFs roll to the

chocks at U.S. Air Force Tactical Fighter Wings around the world.

In awarding the two contracts, Air Force Secretary Edward Aldridge says the new offensive fighters will be needed to counter two Soviet supersonic, all-weather fighters—the MiG-29 Fulcrum and SU-27 Flanker. Both Soviet planes are twin-engine, high-performance machines with improved range, thrust-to-weight and maneuverability. They can carry powerful long-range radars and radar-guided missiles for both dogfights and for beyond visual range, with look-down, shoot-down capability.

Also locked in heated competition are Pratt & Whitney and General Electric for the propulsion that will power this aircraft. They were awarded contracts in 1983 to develop the prototype ATF engines and are rushing to build an engine that satisfies the Air Force's thrust-to-weight ratio of 1.2:1 or better. That means if the aircraft weighs about 50,000 pounds, 60,000 pounds of thrust is required.

Although many of the details of the ATF are cloaked in a black shroud of security, Gen. Lawrence Skantze, commander of the Air force systems command, dropped more than a few hints in a speech last year. He said, "The ATF will leave the transonic flight era behind and thrust us into the age of sustained supersonic combat."

"The cues an adversary will use to try to hunt it down—like infrared, visual radar signatures—will be reduced with low observables technology. Stealth



Slats in X-Wing's rotor will create lift in transition from vertical to horizontal flight. Plane will fly low-level attack, and engage fighters.

will also reduce vulnerability to ground-to-air missiles.

"An integrated electronic warfare system will reinforce the ability to penetrate enemy airspace undetected. An avionics architecture called Pave Pillar will fuse masses of sensor information for a totally integrated avionics suite. With VHSIC (Very-High-Speed Integrated Circuits) we'll require only about $\frac{1}{11}$ th as many integrated circuits as presently used in aircraft electronics. That means far fewer cables and connections, for fewer failures at a fraction of the cost.

"The fighter will aid the pilot in making split-second decisions using artificial intelligence and other technologies like helmet-mounted displays and sights. The Air Force is working on computer voice-recognition and advanced control and displays so the pilot will be able to communicate with his aircraft, and ask for particular displays of data to be superimposed over his visor."

The general is referring to a "pilot's associate," a combination of advanced computerized systems, crammed with artificial intelligence that will help the pilot survive. It will feed the pilot, in simple graphic form, information relative to his own aircraft, mission planning, the enemy's attack, tactics to utilize and communication with aircraft subsystems. The computer systems will have speed, visual and tactile modes. They will utilize infrared, laser and radar sensors in a target recognizer that "looks" at an object—even from a long distance, creates a computerized model from memory of what it thinks the sensors are "seeing" and then compares data from the sensors against the model to determine what the object really is. The single pilot will not be bogged down with an onslaught of numbers and letters. Instead, he will be presented with full-color, programmable, pictorial formats for real-time decision-level systems and mission information. Boeing is even studying the feasibility of incorporating a third dimension to the images pilots will see on pictorial displays. The

single pilot of the ATF will thus be able to concentrate on his number one priority—the mission at hand.

At \$35 million each, the ATF will be the most expensive fighter plane ever to take to the air. It will be able to cruise supersonically at 1.5 times the speed of sound or 1300 mph. It is expected to double the combat radius—out to 1000 miles from its base and return—as well as fly twice as many combat missions in a given period of time. It will also have triple the engine reliability of the current F-15 Air Force fighter, designed in 1969. To create a plane with both range and speed, the ATF is being forged from new materials. Plastics may have been the cry of an earlier generation. Today it is thermoplastics. From 40 to 60 percent of the ATF's structural weight will consist of thermoplastic matrix composites. This will enable the aircraft to fly with the same payload and range at half the empty weight of existing fighters. This should make the ATF 20,000 pounds lighter than fighters built from conventional metal alloys.

Dr. Gary Denman, director of the materials laboratory at Wright-Patterson, explains the use of thermoplastics. "It's kind of like Tupperware," he says. "It's tough and if you ever put it on the stove, you'll know it melts. It's easy to form. But chemical companies are looking hard at ways to improve the temperature capability of thermoplastic materials and I imagine most of the ATF will be made up of them."

To maximize lift and minimize drag for fuel-efficient cruising in the ATF, variable camber wings will automatically change their curvature in flight. Preliminary testing with mission adaptive wings (MAW) on an F-111 operated in a manual mode are coming close to goals of range increases of up to 25 percent for typical supersonic, low-altitude missions and up to 30 percent for normal high-altitude missions.

There are no conventional flaps, slats, ailerons or spoilers on the MAW-equipped F-111. Instead, a composite skin covers flexible leading and trailing edges whose shape is continuously and



Lightness, strength, agility and advanced electronics define LHX. Top speed: 170 knots.

AIR POWER 2000

automatically adjusted by a digital flight control system.

Less is known about the Navy's version of the advanced fighter, the ATA. The Navy has imposed a black security net over the aircraft, but aviation experts reason that the ATA's needs will still be tied to the large-deck aircraft carrier.

The New Rotorcraft

Igor Sikorsky would be aghast. The pioneer of vertical flight would never have imagined that his creation—the helicopter—would one day mesh with such a variety of VERTOLs able to fly at high subsonic speeds. That day is now. Rotary-wing technology is lifting off from the drafting tables at accelerating speeds, with a variety of configurations serving a number of missions. PM looks at the latest creations: the X-Wing, the LHX and the V-22 Osprey.

The X-Wing

The X-Wing, currently undergoing its first tests at NASA's Dryden Flight Test Center at Edwards Air Force Base in California, is an aircraft that takes off and lands vertically, hovers with helicopter-like efficiency and control, then flies at high subsonic speeds. Developed by Sikorsky, the X-Wing is the first aircraft to use a lift and control system to transform its large-diameter rotor into an efficient fixed wing.

What makes all this possible is something called the Coanda Effect—streams of air forced over a curved aerodynamic surface will follow the contour of that surface, entrain the surrounding air, and provide lift. Thus, in some 30 seconds when the rotor is stopped to become a fixed wing, pressurized air is blown through slots along

the 27-ft. length of the blades, producing both aircraft control and lift.

The X-Wing, which is first being tested on a vehicle known as the Rotor Systems Research Aircraft (RSRA) to demonstrate that it indeed can convert from rotor to fixed wing in flight, incorporates pioneering applications of composites, computer and circulation-control aerodynamics. "Here you have something that could fly map-of-the-Earth at some 30 to 40 knots when that was appropriate, go out and do helicopter dogfights and then also fly at 450 to 500 knots and do dogfights with fixed-wing airplanes," says Arthur Linden, engineering manager of Sikorsky's X-Wing project. The X-Wing will also be elemental in improving protection for Navy fleets by flying long-range patrols from small ships sailing well in advance of the main fleet. Once in position, it can then hover for sonar dipping or search and rescue missions.

The LHX

To counter the effectiveness of the Soviet Mi-24 "Hind" helicopter and replace an aging fleet of light helicopters, the Army is developing an agile, high-speed advanced family of rotorcraft in the 8000-pound class. Designed by Boeing Vertol Co. and United Technology's Sikorsky Aircraft, the LHX will field two models of a lightweight, low-cost helicopter—a scout attack version, and a utility version.

The LHX will be powered by twin 1270-shaft-horsepower engines with a top speed of 170 knots and the ability to climb at 500 ft. per minute. It will incorporate very-high-speed integrated circuits, a fiberoptic control system and advanced composites, structures and aerodynamics. One aim of the LHX aircraft is to reduce weight. Thus, composites will be a prime component of the

LHX. One version, known as SCAT, might be flown by just one pilot—assisted by a highly complex system of computer-aided avionics. The pilot will primarily focus on flying with essential flight and weapons information projected on his helmet visor. Systems will be activated by voice commands and it is conceivable the system will be able to talk back to the pilot.

The LHX will be piloted by means of a short, videogame-like stick mounted on the right armrest. The LHX's main core could consist of sensors, processors, displays and controls that will handle navigation, targeting, fire control, flight control, fault detection and other equipment—a stiff technological challenge.

The V-22 Osprey

The V-22 is a tilt-rotor aircraft combining a modern turboprop plane with the vertical take-off and landing capabilities of a conventional helicopter. It will

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Here's Your Free
PM Wall Poster

Carefully tear along perforation to remove.

cruise at 275 knots and carry combat payloads more than 1000 nautical miles. The joint Bell Helicopter Textron/Boeing Helicopter design currently moving toward production will use forward-swept-wing technology and advanced composites. It will have great utility for all the armed services: The Marine Corps sees it as a medium assault transport; the Navy for combat search and rescue, special warfare, fleet logistics and antisubmarine warfare; the Air Force for long-range insertion and extraction of special operations forces; and the Army for aeromedical evacuation, combat transport of troops and supplies and other support functions.

Bell Helicopter Textron, Inc., and Boeing Vertol Co., the tilt-rotor team, like to boast of the Osprey's potential: twice as fast as a helicopter, twice the range, can carry a comparable payload twice as far and twice as fast as today's helicopter, increased survivability and reliability, plus easier maintainability.

The V-22 will be the earliest advanced technology aircraft to enter the four services, with a first flight scheduled for 1991. But its impact will be felt far into the next century. Consider the venerable C-130. Designed in the early '50s, it's still ferrying troops and equipment. Likewise, today's concepts for ATB, ATF, X-Wing and LHX will be flying at least until 2025. More than advanced aircraft, today's aviation concepts thus become our legacy of flight. **PM**

The V-22 Osprey will take off like a helicopter and fly like a plane using tilting engines. A cross-link system operates both blades on one engine if one powerplant fails.



About 500 men died for every mile of the 50-mile-long Panama Canal, four-fifths of them under the old French canal company. Yellow fever and malaria were prime causes, but even with disease under control the construction of the canal was a struggle.

Men, steam shovels and dirt trains strained and slipped in the mud and rain at the bottom of the deep trench—the nine-mile Gaillard Cut—through the continental divide. The total excavation was enormous—310 million cubic yards, counting the French effort. The spoil would fill dirt trains encircling the Earth four times at the equator, or build a pyramid seven times higher than the Washington Monument.

More explosive energy than had been used in all the nation's wars up to 1914—the year the canal opened—was needed to blast the cut through high elevations. And time after time thousands of tons of rock and dirt cascaded down onto men and machines as the sides of fractured mountains suddenly and unexpectedly slid into the cut.

Today the Panama Canal is quiet, the din long since gone. From a vantage point on the deck of a freighter, one watches the big lock gates swing open; the peace is disturbed only by the muffled whine of winches as the electric mules haul the ship through. Nothing disturbs the beauty of Gatun Lake. The water laps gently at the edges of the jungle as ships pass. Even Gaillard Cut, scene of many a landslide, has been relatively quiet since 1975.

Ahead of its time

The Panama Canal has served world trade and national defense for nearly 64 years. While its design was far ahead of its time, ship traffic and technology have been catching up, especially in the last two decades.

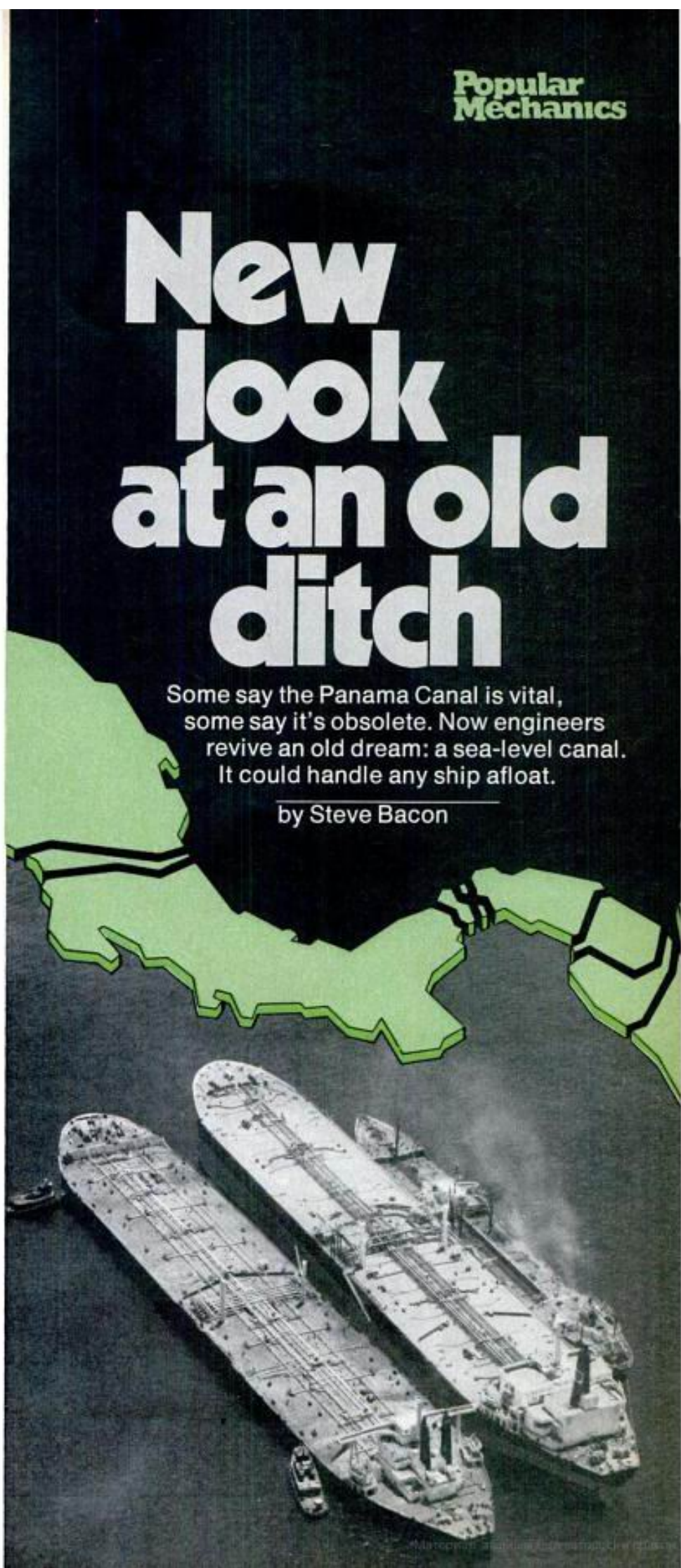
The number of ships using the

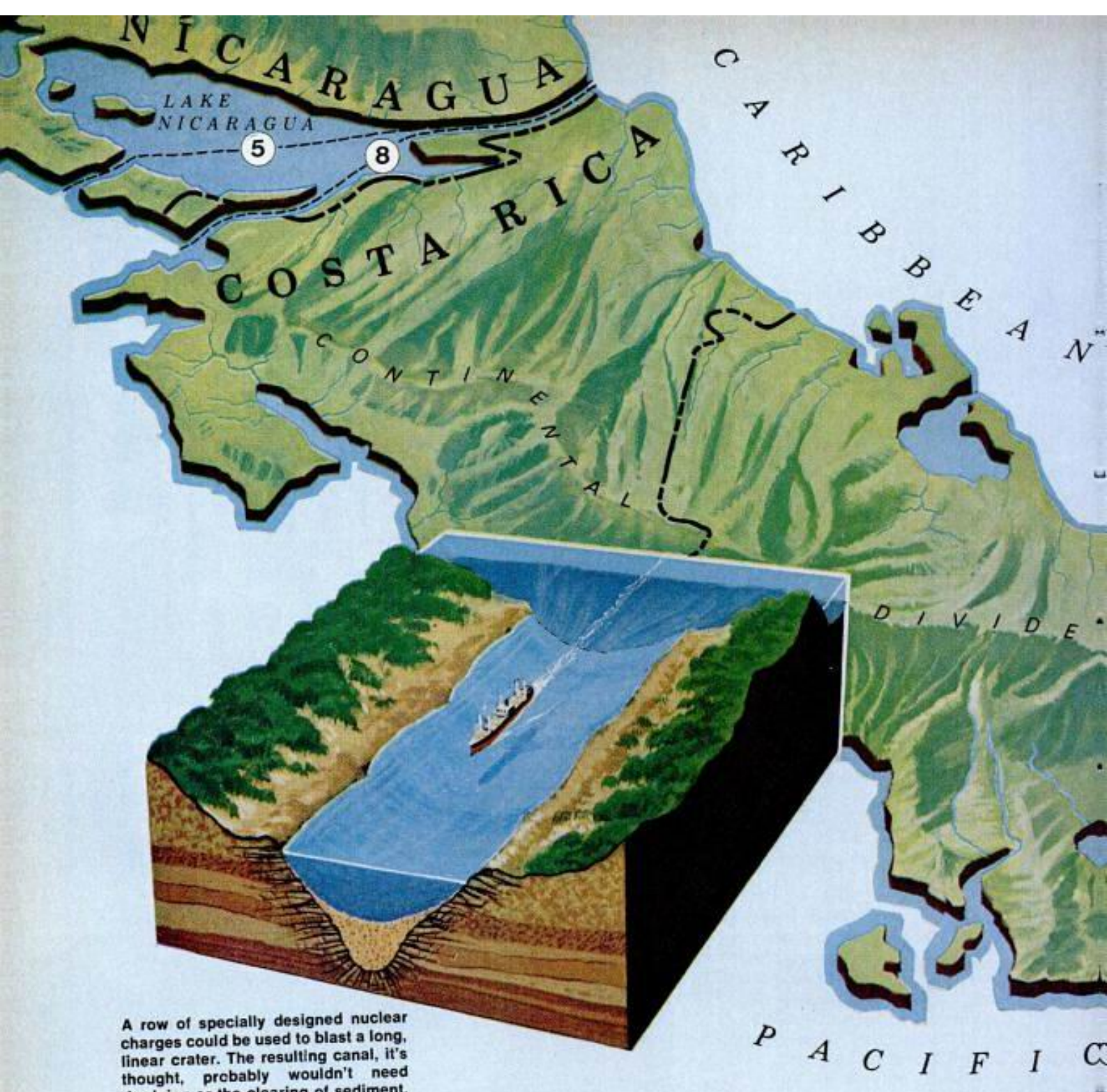
New look at an old ditch

Some say the Panama Canal is vital, some say it's obsolete. Now engineers revive an old dream: a sea-level canal. It could handle any ship afloat.

by Steve Bacon

Supertankered to Panama, Alaskan oil must be pumped to storage tanker (center) for transfer to carriers that fit the canal.





A row of specially designed nuclear charges could be used to blast a long, linear crater. The resulting canal, it's thought, probably wouldn't need dredging or the clearing of sediment.

canal more than doubled between 1950 and 1970, and the cargo carried through it increased by nearly 400 percent. Despite the fact that the waterway has been lighted its entire length and put on a 24-hour schedule, it will reach the saturation point—26,800 ships annually—some time between 1989 and 2000.

Although the canal could handle the biggest ship afloat in 1914—the 52,000-ton, 5500-passenger *Imperator*, larger than the *Titanic*—vessels have begun to crowd the 110-by-1000-foot locks. The reason: Ore and grain carriers, container ships and oil tankers have grown to sizes that

would have been beyond comprehension as recent as a dozen years ago.

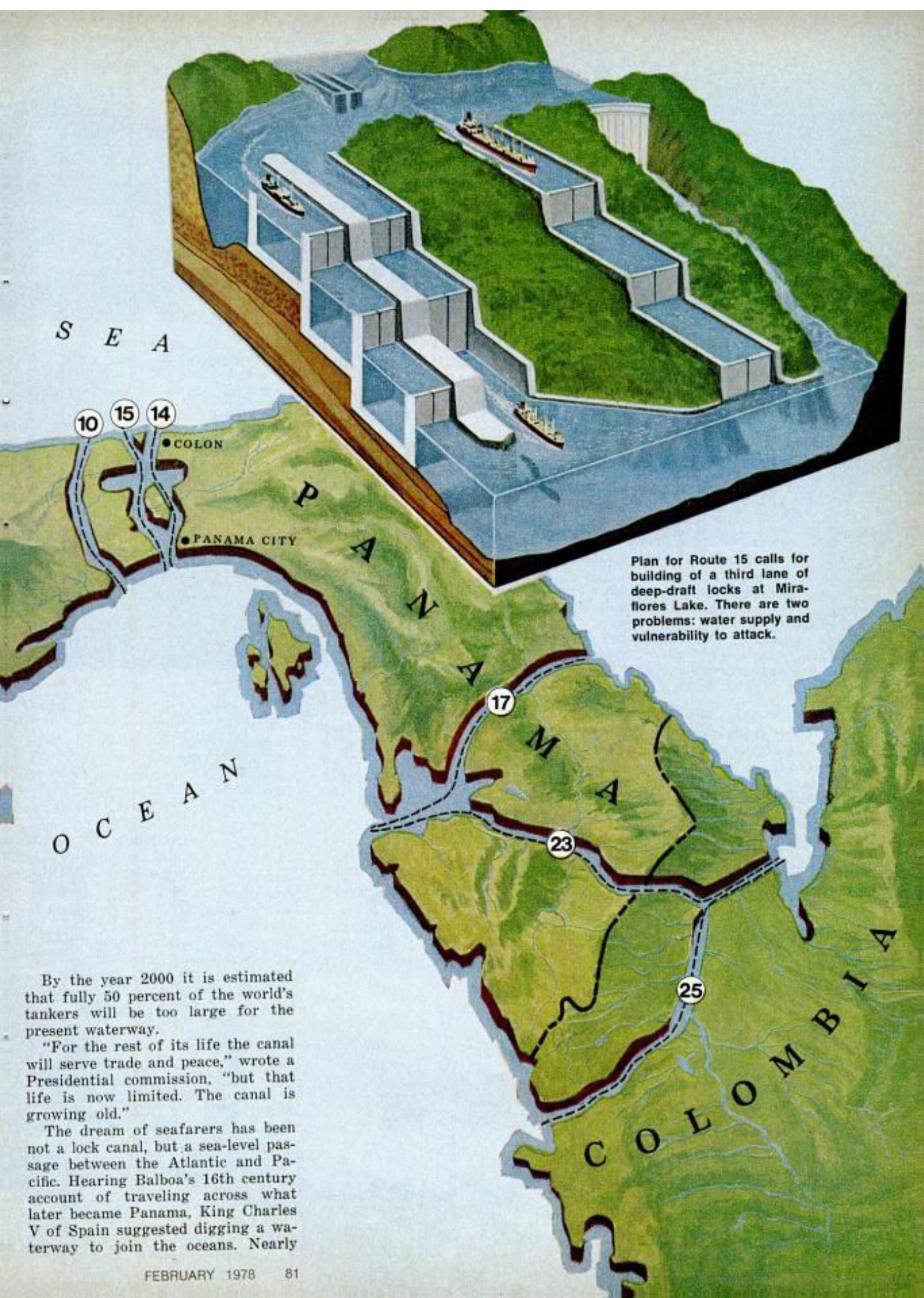
The problem is highlighted by North Slope oil bound for the lower 48 states. Just last August a tanker of 265,000 deadweight tons (DWT, ship cargo capacity in *long tons*), arrived off Panama. It was the S.S. *New York* with the first oil from Port Valdez, Alaska. The only way to get crude through the canal is to use a seagoing "petroleum depot" and a fleet of smaller tankers.

Serving as the depot is the supertanker M.V. *British Resolution*, which will remain anchored 65 miles

from the canal until a land-based oil terminal can be built. It took on 1.8 million barrels of oil from the *New York* and pumped it into smaller shuttle tankers bound for the Gulf Coast via the canal.

Carriers can't make locks

As early as 1970 a survey revealed that a total of 1300 ships were then too wide for the Panama locks. (To this figure add all of the U.S. Navy's aircraft carriers.) Yet another 1750 vessels were unable to go through the canal fully loaded, for their capacity exceeded the canal limit of 65,000 DWT.



Plan for Route 15 calls for building of a third lane of deep-draft locks at Miraflores Lake. There are two problems: water supply and vulnerability to attack.

By the year 2000 it is estimated that fully 50 percent of the world's tankers will be too large for the present waterway.

"For the rest of its life the canal will serve trade and peace," wrote a Presidential commission, "but that life is now limited. The canal is growing old."

The dream of seafarers has been not a lock canal, but a sea-level passage between the Atlantic and Pacific. Hearing Balboa's 16th century account of traveling across what later became Panama, King Charles V of Spain suggested digging a waterway to join the oceans. Nearly



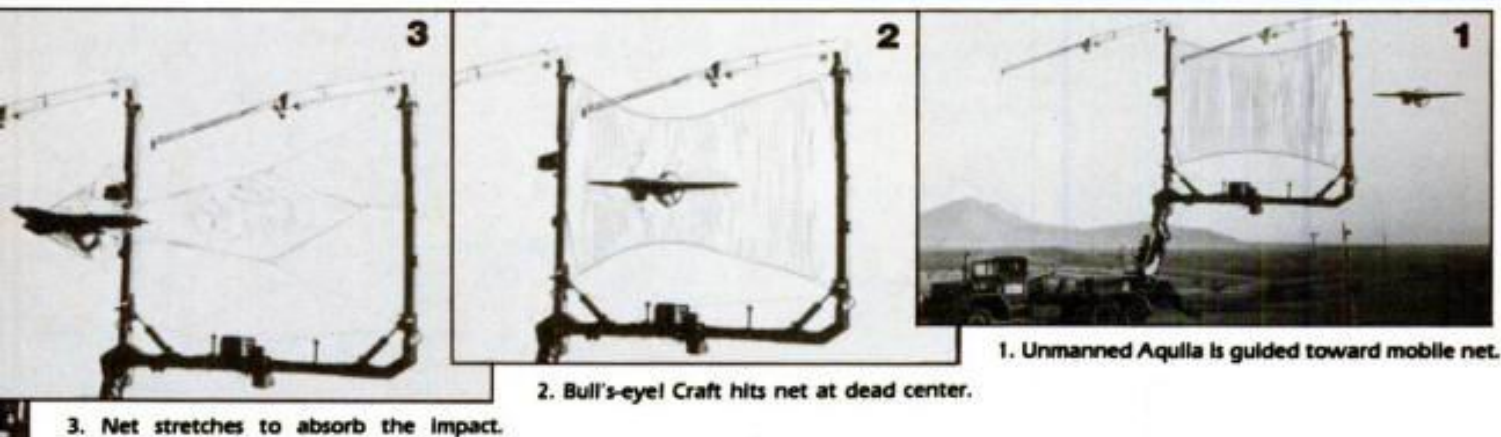
Far-out flying machines for the 21st century

When not building airplanes for the present, engineers at the Lockheed-Georgia Co. like to dream about futuristic concepts for the next century. Some of the far-out ideas they come up with are dillies. Imagine an antisubmarine patrol craft able to remain at sea for days at a time without returning to base. In between reconnaissance missions, the huge amphibious Sea Loiter (upper left) would just park in the water, becoming a floating outpost ready to take to the air at a moment's notice.

The Delta-Wing Spanloader (upper right) is a giant, all-wing cargo transport designed to eliminate the weight and drag of a conventional fuselage. Its airfoil shape, thick

enough to accommodate boxcar-size loads, converts the entire structure into a lifting surface, enabling it to haul 400-ton payloads more than 4,000 miles.

Or take the Flatbed Freighter (lower right). It would carry containerized cargo on its open spine, making loading and unloading much faster and easier than in a cabin plane. Perhaps the strangest concept of all is the Ground-Effect Transport (lower left). A flying boat with cupped wings, it would fly across the ocean only a few feet above the surface without ever getting out of ground effect. Riding a cushion of air, the 238-foot-long water skimmer could carry 220-ton payloads at better than 300 mph.



Gotcha! New aerial snatch saves spy planes

Launching an RPV (Remotely Piloted Vehicle) is easy, but getting it safely back down is another matter. It has no wheels and can't be landed like a conventional airplane. Until recently, such unmanned observation craft were recovered by parachute—a slow method that subjects them to enemy fire and ground impact damage.

The U.S. Army's newest RPV spy plane, the Lockheed-developed Aquila, has no such problems—it's snatched right out of the air on the fly, as shown in the photo sequence above. After a reconnaissance mission, it's guided back to the launch site and flown into a mobile capture rig that looks like a place kicker's net stretched between

football goal posts. The net is designed to give way progressively, slowing the craft and forming a U-shaped sling to cradle it. The sling is then lowered to the ground.

The retractable capture rig, which mounts on a standard five-ton Army truck, can be moved quickly to any location and set up in minutes. The Aquila RPV, fitted with TV cameras and sophisticated surveillance gear, will give the Army a new set of long-range electronic eyes for peering deep into enemy territory.

Editor: Dennis Eskov
Contributors: Sheldon M. Gallager, Jack Hammond,
Michael A. Fillon, Phyllis Wolfman, John Ginsberg

AVIATION

Biggest planes ever

Huge cargo planes with designs you've never seen before could cut shipping costs by 40 percent, move monster bulldozers from factory directly to strip mines and, adapted for people, let you ride in the same comfortable seat from center city to center city.

Years before the first of these giants takes off, aircraft designers have begun favoring some designs. The two-fuselage freighter shown below, for instance, is now considered more likely to enter production than designs calling for three bodies.

Whatever the final designs, the launching of these planes should be good news for companies with high shipping costs, and ultimately for consumers. Planes envisioned by researchers will carry payloads up to 600,000 pounds, three times that of today's largest cargo planes. Despite a gross weight sometimes exceeding a million pounds,

these planes will fly farther and burn less fuel than today's. They may even be quieter.

These advantages will surface from research to explore composite materials, reduce airstream drag on wings and fuselage, apply advanced electronics and possibly use alternate fuels, such as liquid hydrogen (see *Hydrogen: New Kick for Cargo Planes*, page 118, May '80).

Two versions shown below are on the drawing boards at Lockheed-Georgia. (At NASA's urging, Lockheed, McDonnell-Douglas and Boeing are working on "Very Large Aircraft.")

Lockheed's double-fuselage model will fly a payload of 441,000 pounds at a speed of Mach 0.80 with a range of 4000 nautical miles. Lockheed's advanced concepts department manager, Roy H. Lange, said this version of the big carriers has the best current chance of going into production.

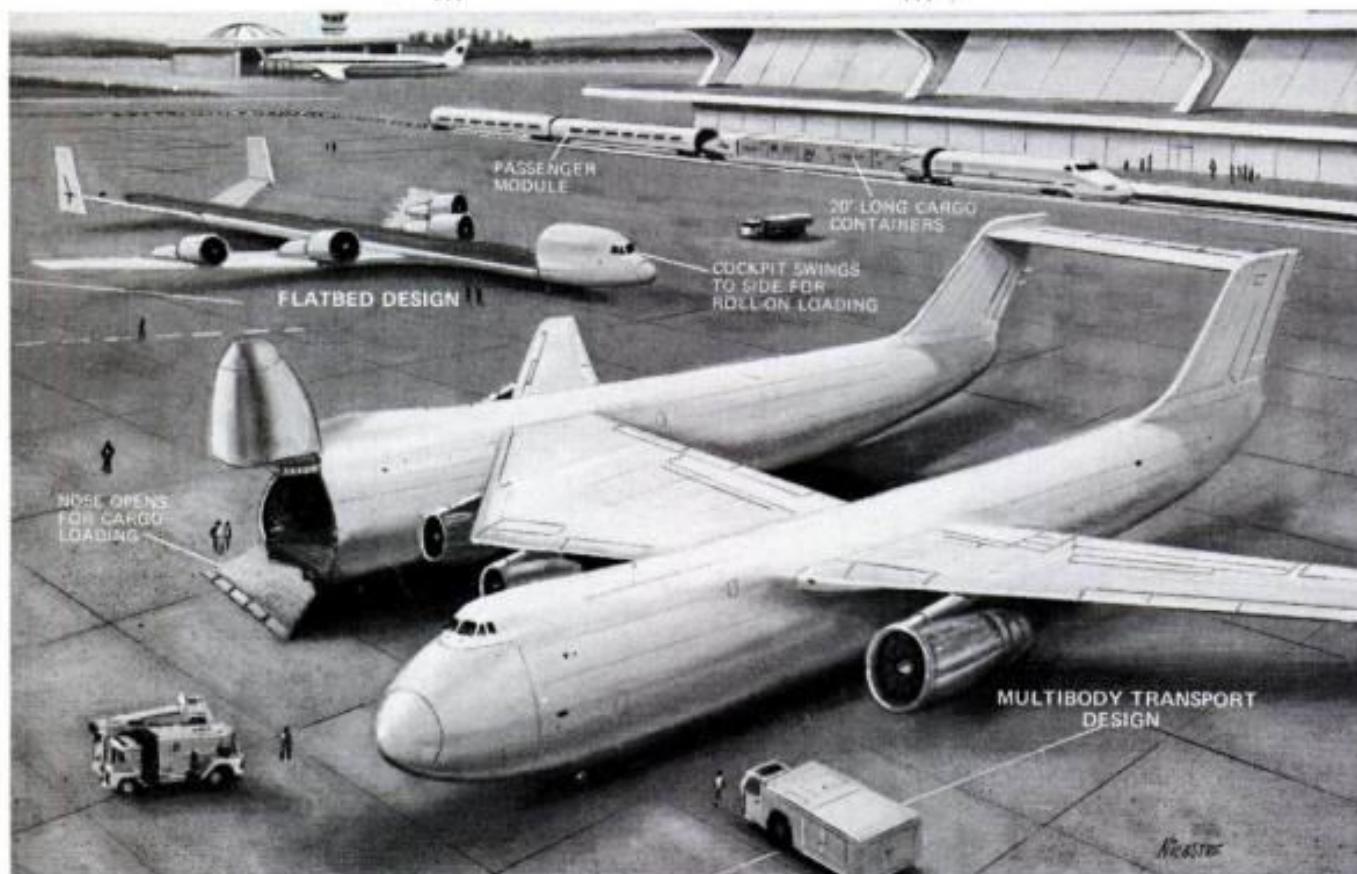
"We also have a triple-fuselage model on the boards," Lange said, but he gave it less chance of flying someday than the two-body carrier. Lange's reasons:

The three-body model would put more stress on the wing. Production would be more efficient if all fuselages were alike. And the proportion of body surface area is higher in the three-body version, creating more drag.

One of Lockheed's more innovative concepts (also below), looking like the toss-away portion of a filleted fish, is called a flatbed design. Its skeletal configuration gives the plane versatility unmatched by other carriers. Modeled after Lockheed's C-141, the flatbed model's payload is 75,000 pounds. Lockheed design engineer Rollo Smethers points out this concept is easily adaptable to much larger planes.

A passenger module that locks onto the flatbed makes the jet look as normal as today's planes. But the clincher, says Smethers, "is the fact that the module could be boarded in midcity, conveyed by rail to the airport, attached to the plane's bed, flown to its destination and sent to midcity by rail again."

How soon will these planes be airborne? "Some time between 1995 and 2000," Lange says. **PM**



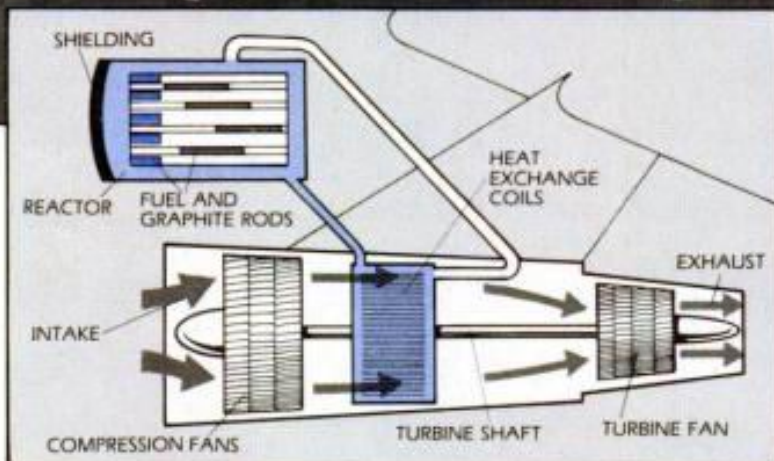
Double-fuselage cargo plane will haul 441,000 pounds; flatbed plane (at rear) will adapt for boxcars or passengers.

AVIATION



Will atoms take off?

A nuclear-powered airplane could be airborne by the 1990s if the military or an airline company ordered one, according to our sources at the Air Force Institute of Technology. In 1961, the government scrapped the idea of a nuclear-powered jet, but the concept was revived in the past few years by a team at Wright-Patterson Air Force Base. The key strategic use of an atomic plane would be in submarine surveillance: The A-Plane would use two conventional engines to get off the ground, but a pair of nuclear-powered engines could be fired permitting the craft to stay aloft for months at a time. The airplane envisioned is of a canard-type design, allowing engineers to place the reactor farther away from the crew than would



have been possible in the '60s. The reactor, a high-temperature helium-cooled type, would send heat through heat exchange coils surrounding the turbine shaft. That would help compress intake air to turn the jet's turbine fans.

Return of the P-51



No belly scoop, but still a familiar sight.

Although it lacks the original's distinctive belly scoop, the plane you see above is almost a direct copy of the famous P-51 Mustang fighter of World War II. Called the Piper Enforcer, it's designed as a low-cost companion to the much more expensive tank-busting A-10 dive bomber.

Why build a new ground-attack aircraft based on a 40-year-old design? The answer: proven capability at a bargain price. Enforcers cost about \$3 million apiece, compared to as much as \$18 million for the A-10.

The 2,445-hp turboprop plane carries assorted cannons, missiles and bombs and can do 403 mph—making it actually a tad slower than its illustrious ancestor.

Poor man's AWACS



Bargain AWACS: Tiny blimp with big eyes.

Flying radar stations like the AWACS and Hawkeye can be an effective war deterrent, but are too costly for use by many friendly nations of the Third World.

Now, however, the U.S. Air Force thinks it may have found a simple, low-cost substitute that anyone can afford—a small blimp fitted out to carry sensitive radar detection gear in an underbelly pod.

The 250,000-cubic-foot, helium-filled airship, currently being tested at Homestead AFB in Florida, is 175 feet long, operates at altitudes up to 12,000 feet and can be remotely controlled from the ground with no crew aboard—just in case some "unfriendly" takes potshots at it.



4. Safe in sling, Aquila is gently lowered.

Popular Mechanics Magazine

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WRITTEN SO YOU CAN UNDERSTAND IT

Vol. 78

DECEMBER, 1942

No. 6

The AGE of AIR



By Colonel Edward S. Evans

President of Evans Products Company

WHO could have envisioned in 1928, when a dozen young men were making the first glider experiments at the University of Michigan, that the crude ship then used was the forerunner of what would ultimately be one of the world's great means of transportation?

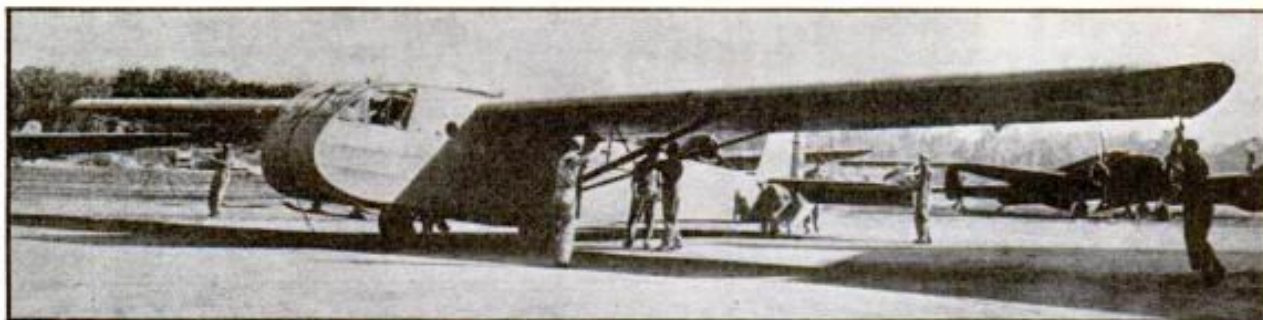
These members of the first glider club

Three huge cargo gliders taking off from an air depot of the future are in the air before the giant tow plane. At upper right, stowing freight in a glider

DECEMBER, 1942

1

*Wilma Lee, Public Relations,
Evans Prods. Co., Tullerton at Greenfield,
Detroit, Mich.*

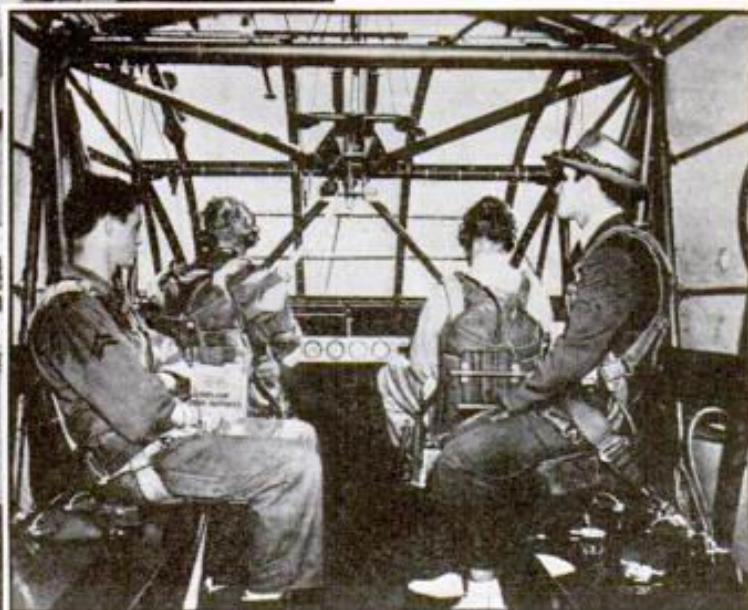
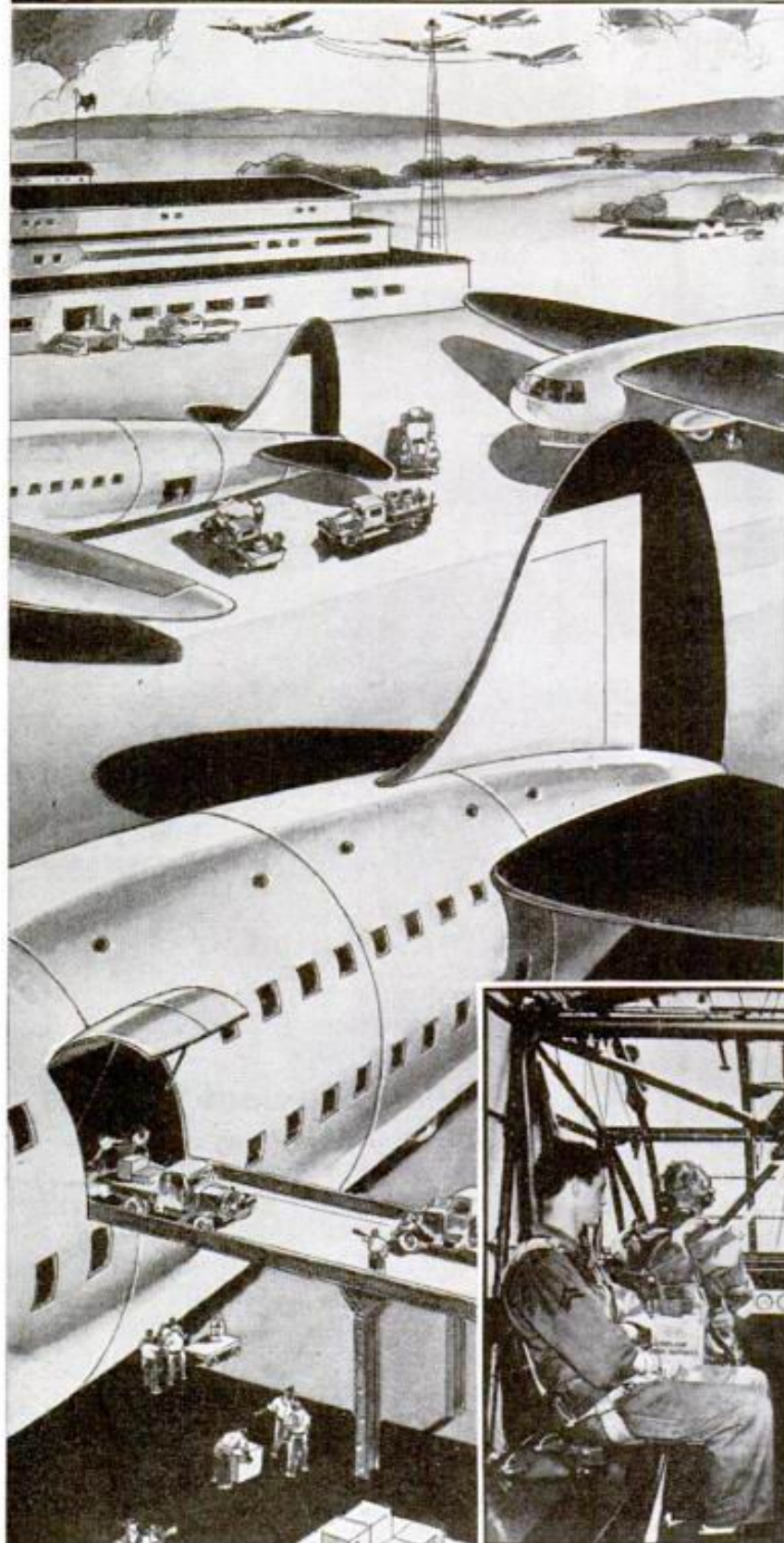


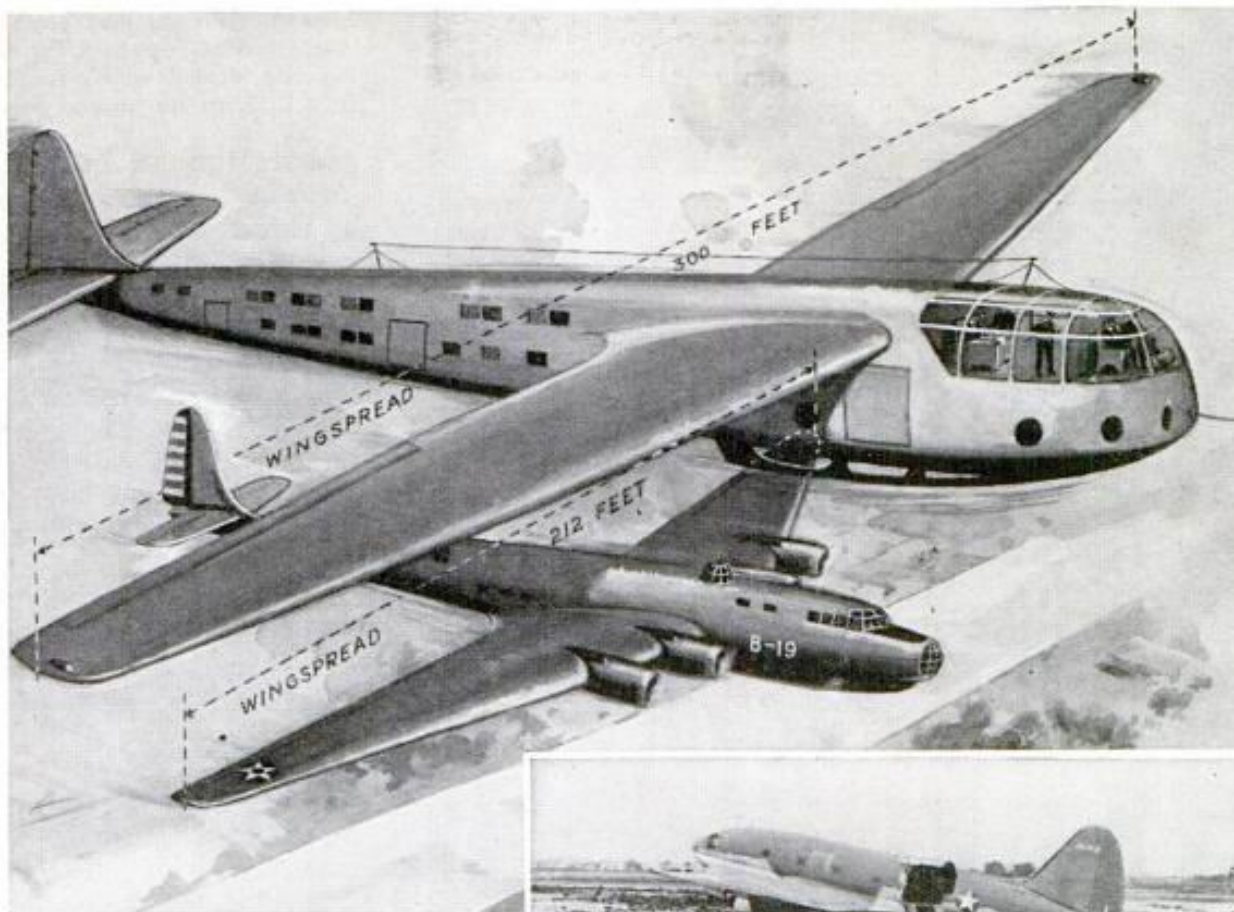
15-seat gliders of U. S. Airborne Command are only a beginning

of America, which was formed under my sponsorship, learned the delight of being pulled into the air with a rubber cord and gliding gently to the ground several hundred yards away. Some of these same young men today are still flying gliders, beautiful ships known as sailplanes which have established records of distance, altitude and duration that are almost unbelievable.

Looking toward tomorrow, we can see the same principle employed for motorless cargo ships towed by tractor or tug planes, carrying enormous loads of freight or deliver-

All perishable and first class cargo eventually will be shipped economically by air, says Colonel Evans. Left, air freight terminal; below, cockpit of army glider





The author foresees a motorless freight and passenger ship with a 300-foot wing spread—nearly 100 feet wider than that of the B-19, drawn to same scale, above



Transport planes of the Airborne Command (above and at left) are vast enough to carry army jeeps and large number of men

vibration, no noise, with a wing span and a speed which will assure smooth riding. One employing such facilities can rest comfortably at night and arrive at his destination as rested as if he had slumbered in his own bed.

ing human cargo in the most quiet and delightful way ever known to man; ships that will carry twenty tons or more freight or up to 100 passengers, with no engine

Freight thus transported could be delivered in quantity at 200 miles per hour and at a cost well within the range of economical shipping; in other words, somewhere

The CAPITOL Nobody Knows

by Bill and Juana Wilson

HOUSE

1. House Majority Conference Room
2. House Minority Conference Room
3. Congressional Ladies' Reading Room
4. Office of the Speaker
5. House Reception Room
6. Committee on Ways and Means
7. Grand Staircase-East*
8. Formal Office of the Speaker
9. Parliamentarian
10. Members' Reading Rooms
11. Speaker's Lobby
12. House Chamber
13. Library
14. Cloakrooms
15. Committee on Appropriations
16. Grand Staircase-West*

17. House Minority Whip
18. Statuary Hall*
19. House Document Room
20. House Subcommittee on Foreign Affairs
21. Representative's Private Office
22. House Minority Leader's Office
24. Prayer Room for House and Senate

SENATE

- 25-30. Senators' Private Offices
31. Senate Disbursing Office
32. Senate Minority Leader's Office
33. Secretary
34. Grand Staircase-West*
35. Chief Clerk
36. Bill Clerk and Journal Clerk
37. Official Reporters of Debates



*** John Q. Adams still prowls in Statuary Hall
say janitors; ** busts of dead justices nod in the
small hours. ***** From the empty tomb in the
crypt to its traveling giant dome, our nation's
capitol building abounds in mysteries beginning
with its lost cornerstone. *****

- 38. President's Room*
- 39. The Marble Room
- 40. Senators' Private Lobby
- 41. Senate Chamber
- 42. Cloakrooms
- 43. Formal Office of the Vice President
- 44. Senate Reception Room*
- 45. Office of the Vice President
- 46. Senate Majority Leader's Office
- 47. Grand Staircase-East*
- 48. Senate Conference Room*
- 49. Executive Clerk
- 50. Old Senate Chamber
- 51. Senate Minority Whip
- 52. Small Senate Rotunda*
- 53-58. Senators' Private Offices

* Open to the public



ON A SUMMER EVENING, recently, a tall, middle-aged colonel approached Sgt. Joseph H. Reid of the National Capitol Police who was on duty outside the brightly lighted Capitol in Washington, D.C.

"What building is this?" he asked.

The colonel's failure to recognize his country's Capitol is, oddly, fairly commonplace. Many Washington visitors confuse it with the White House.

Since the sixth anniversary of the signing of the Constitution, Sept. 18, 1793, when George Washington wielded a marble-headed gavel and silver trowel to lay the Capitol's first cornerstone, visitors have formed a never-ending pilgrimage to the site. It's a good thing they don't all ask to see the original cornerstone. *No living person has seen it, and no one knows where it is.*

Capitol Architect J. George Stewart hoped that dismantling the building's east front in 1958 might uncover the block, but it was not located. Its documented position is in the southeast corner of the Capitol's original north wing, below the old Senate Chamber. But today's new extension to the east front (completed in 1961) seals off that portion of the building, making it unlikely that the cornerstone will ever be located. What's more, the Capitol's original plan has been lost too!

It is little short of a miracle that the graceful building which today crowns Capitol Hill somehow escaped becoming an architectural nightmare. Its design was the work, not of an architect,

SCIENCE

FERTILIZING BOAT

SHALLOW LAGOON

BLUE WHALE SPOUTING

BALEEN FOOD STRAINER

BLUE WHALE

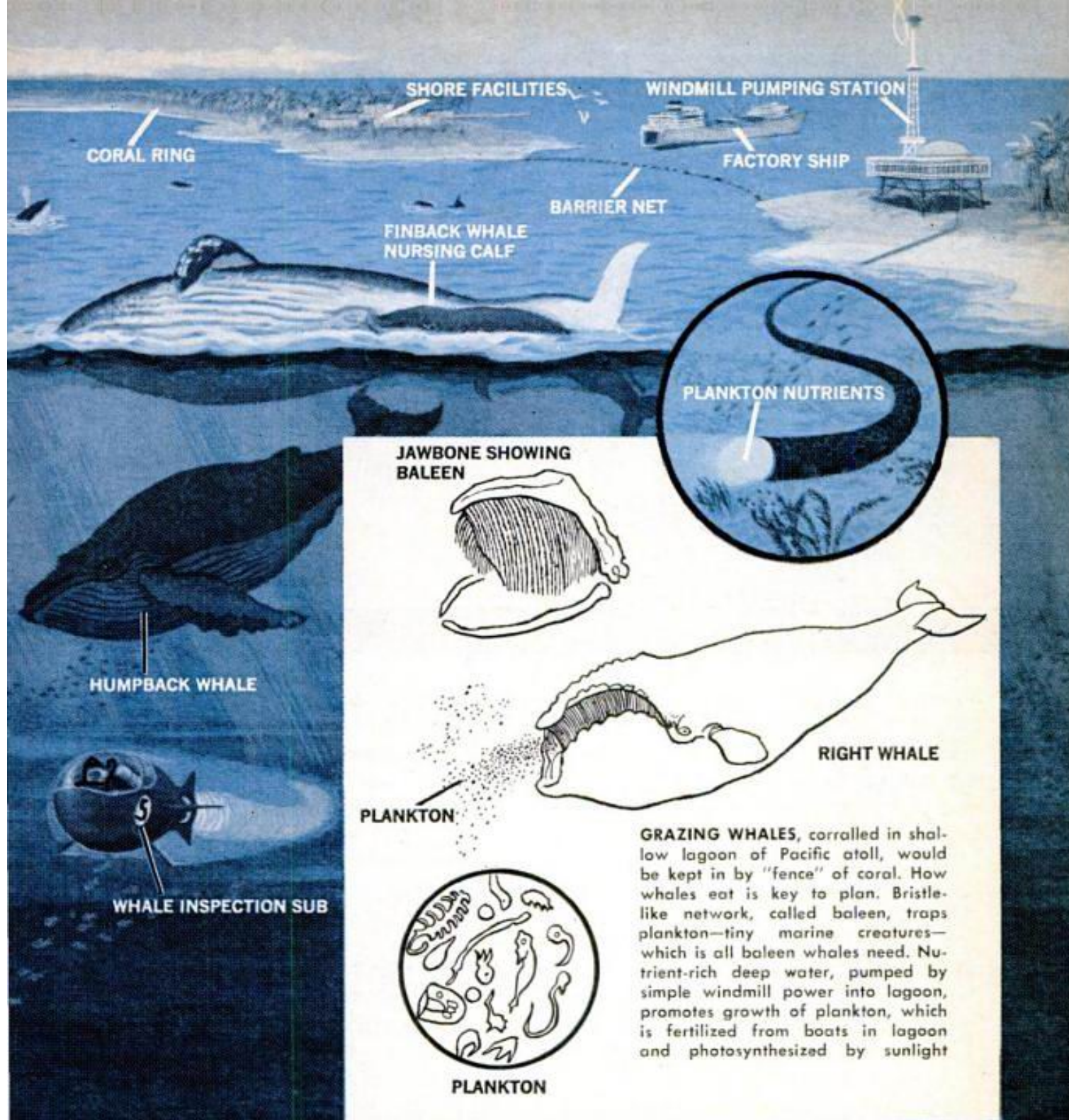
TONGUE

WHALE FARMING IN A CORAL CORRAL

Man has domesticated other animals. Why not the largest one of all?

By KEVIN V. BROWN

Illustrations by Miller Pope

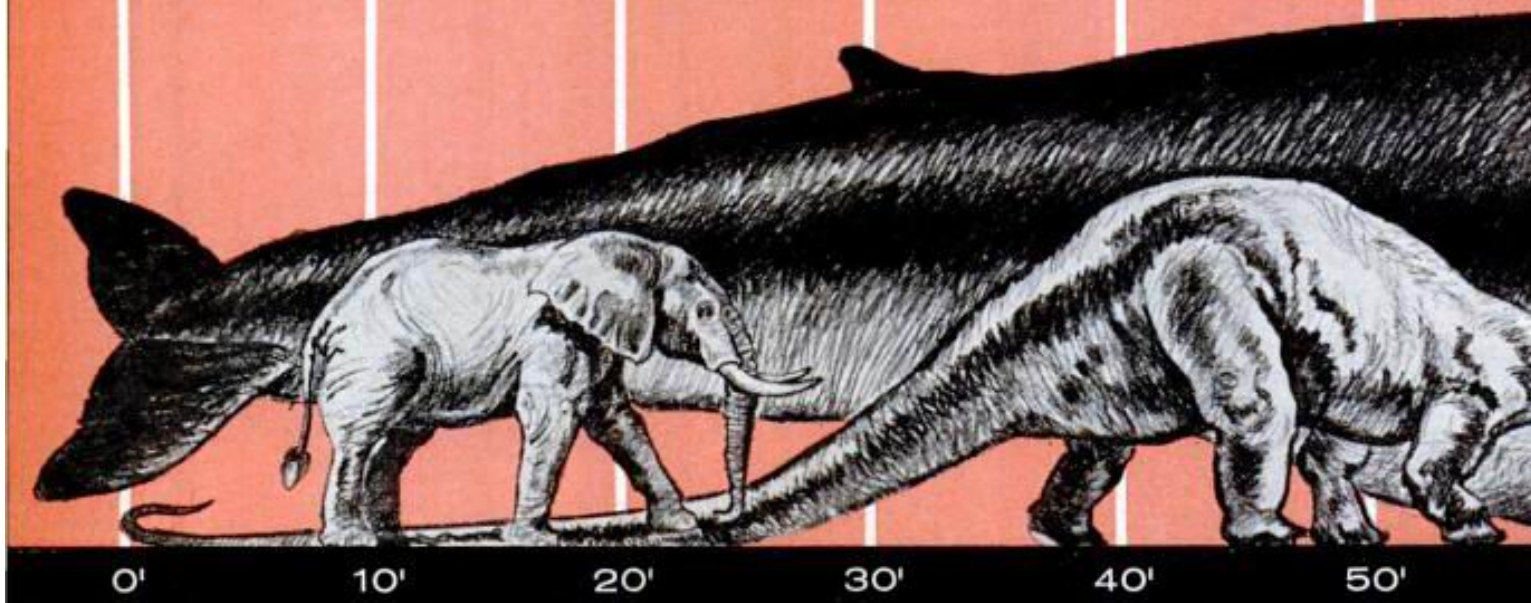


HOW DO YOU LIKE your whale steak—rare or well done? You may have a chance to find out. If so, your choice cut may someday come from a whale "farm" far out in the Pacific Ocean where the mighty mammals could be bred and fattened up for eating in much the same way that cattlemen raise beef on the hoof.

While whale meat may not become a standby on American dinner tables, it may well be an answer to the world's rapidly worsening food shortage. With many underdeveloped and overcrowded regions already facing near-famine conditions, a fresh, new source of food is urgently needed. Whales may be that source.

A plan to establish whale farms in the Pacific, using circular coral atolls as natural pens or corrals, is exciting serious interest. Fenced in by rings of coral, the whales would breed and graze contentedly, growing plump for later slaughter. The proposal was made recently by Professor Gifford B. Pinchot, a biologist for the

THE WHALE is the largest creature ever to live on Earth; larger than elephants, even prehistoric dinosaurs. Food potential from such an animal might help solve world's critical food shortage



Johns Hopkins University, Baltimore, Md. Into Prof. Pinchot's plan dovetail many of the world's great challenges: expanding populations, diminishing food supplies and, especially, the immense, untapped resources of the sea.

"We still hunt, rather than farm the ocean," he argues.

In its simplest terms, his plan goes like this. It has its roots in the fact that all life depends on using energy from the sun in photosynthesis to convert inorganic nutrients into organic food-stuffs, a process carried out by plants on land and in the ocean.

"All the rest of us," he says, "those who are not capable of photosynthesis, live either directly or indirectly on these plant products."

And, Prof. Pinchot goes on, oceans cover almost three-quarters of the surface of the earth, so they receive roughly three times as much sunlight and are potentially three times more capable of food production.

So "farming" the ocean would involve seeding, fertilizing and harvesting it just as we do the land.

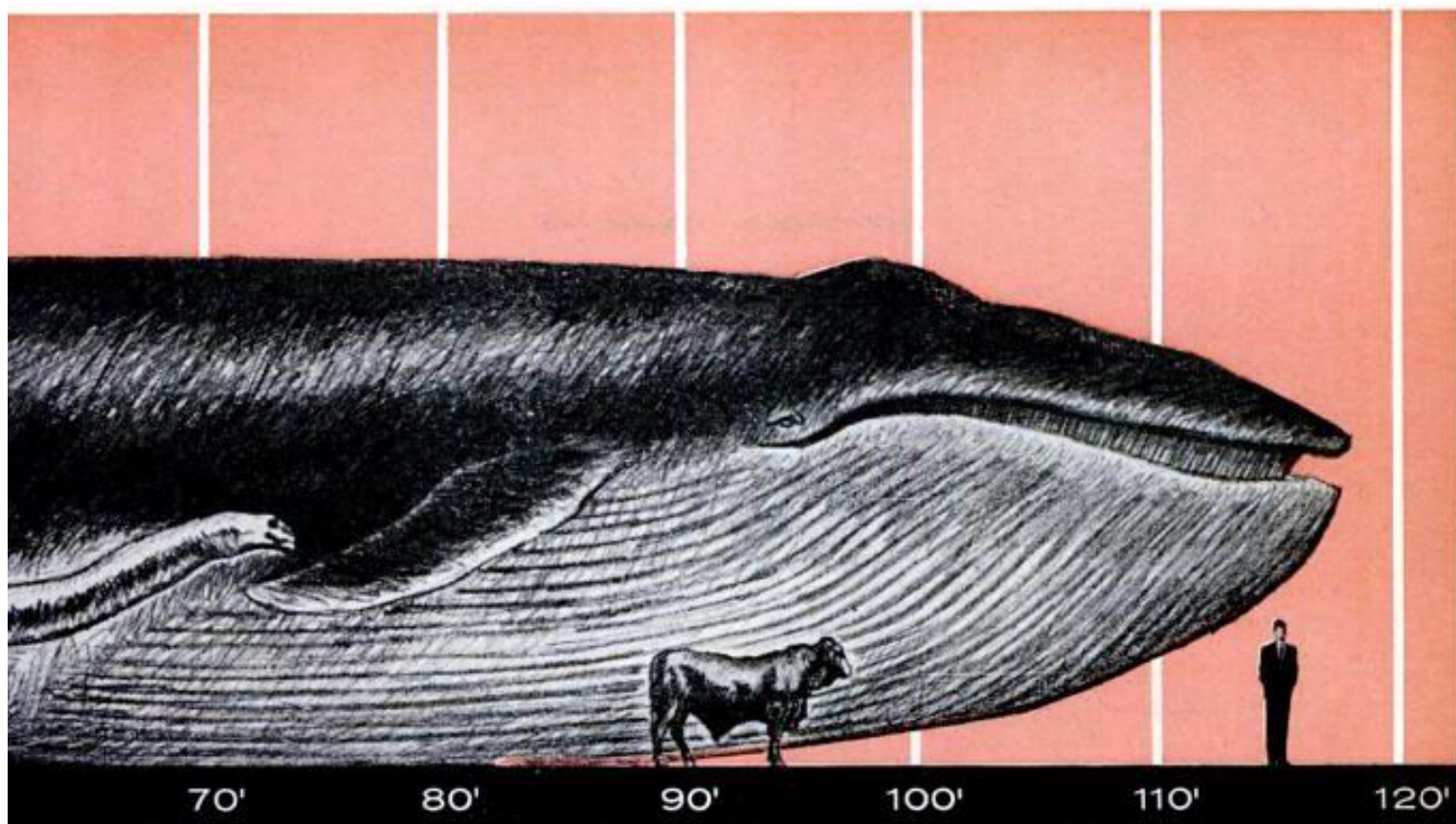
Enter the whales. Prof. Pinchot chose whales for the obvious reason—they're

the biggest mammals that ever lived—but for other reasons that conservationists and sociologists would applaud. They've been hunted almost to extinction and could use some help from man to survive. Also they are a great source of animal protein.

Not only is the world's food supply dwindling in relation to its expanding population, but even in areas where food is available, there's a shortage of animal protein, and some sources blame half the deaths of children between one and five in underdeveloped areas on the lack of animal protein.

But how do you domesticate a whale in the same way as a Hereford steer? Prof. Pinchot's plan is to use tropical lagoons in the center of coral islands. These islands are actually the tops of extinct underwater volcanoes, so the area within the ring or lagoon is relatively shallow, and the openings could be closed off by underwater fences. A coral corral.

Whales, like any other animals, have only two basic needs: food and the propagation of the species. If they're content, they'll take care of the propagation themselves, and food will be



the only problem. Just as the farmer brings feed to his livestock to fatten it, the whale farmer would have to do the same. And we're back to photosynthesis.

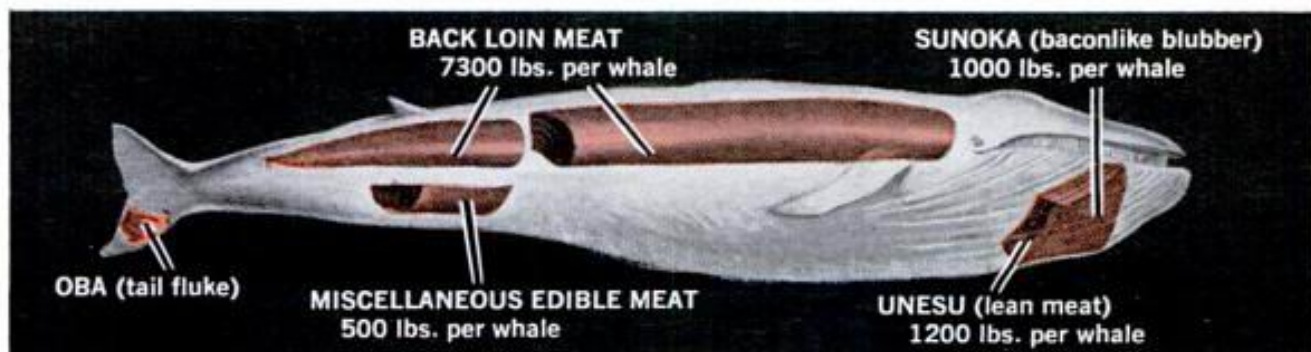
Most whales, notably the blue, humpback and sei species, live almost entirely on infinitesimal plants and creatures called plankton. Killer and sperm whales are carnivorous, so they could not be raised under these conditions.

Tropical waters are rich in inorganic nutrients, but not at the surface. Pinchot would draw nutrients from deep outside the coral reef, perhaps with windmills, and pour them into the coral corrals where they would be fertilized by man, photosynthesized by

nature and consumed by contented whales.

Whales used to be hunted for their oil with their meat as a lightly regarded by-product. Now, however, with other, less expensive sources for oil, whales are looked to more for their meat.

Capturing the whales initially would not be a major problem, although the logistics would be whale-sized. They could be drugged and towed to the corrals. Hopefully, after that nature would take its course and the whale population would increase in size without any help from man. At slaughter time, these chores could be carried out on shore facilities on the corral ring or, as they are done now, on whaling ships. ★ ★ ★



EDIBLE MEAT from just one blue whale would total five tons, equivalent of more than 20 good-size steers
OCTOBER 1968

Your Victory Home

POPULAR MECHANICS MAGAZINE



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SEE PAGE 1

Popular Mechanics Magazine

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WRITTEN SO YOU CAN UNDERSTAND IT

Vol. 81

FEBRUARY, 1944

No. 2



Striking a point where a trestle is out, the auto-railer freight retracts its steel wheels and takes to the highway

By E. S. Evans

TO THE young man of yesterday it seemed that the words of Horace Greeley, "Go west, young man," no longer had the inspiration and thrill they once possessed. No longer were there frontiers to be crossed and new discoveries to be made where fortunes could be acquired through adventure and daring. The horizons had closed down. No longer were there gold rushes or homesteading. No longer were territories being opened up for new settlers, and men had to find their fortunes at home in the hard way.

Col. Edward S. Evans, president of the Evans Products Co., supervised freight loading for the Quartermaster Corps in World War I, has since become one of our leading inventors and manufacturers of automotive, rail and aviation equipment. Here he presents his unique proposal for an auto-railway to Alaska

Now a thrilling development in transportation once more opens the door to wonderful new adventure. New lands rich in natural resources, holding out attractions for industrialists, agriculturists, miners, and in fact, every walk of life, can be brought within range of modern energies.

Let me draw you a picture. We are driving down a highway paralleling a railroad. Swiftly, silently, on the railroad there comes a Diesel-powered train with locomotive and 25 cars. Ahead there is a bad washout; the rail-



With steel pilot wheels lowered, the pneumatic tires of the auto-rail freighter ride on the rails

drop into place and serve as pilot wheels. There has been little or no delay in this off-the-track, on-the-track movement.

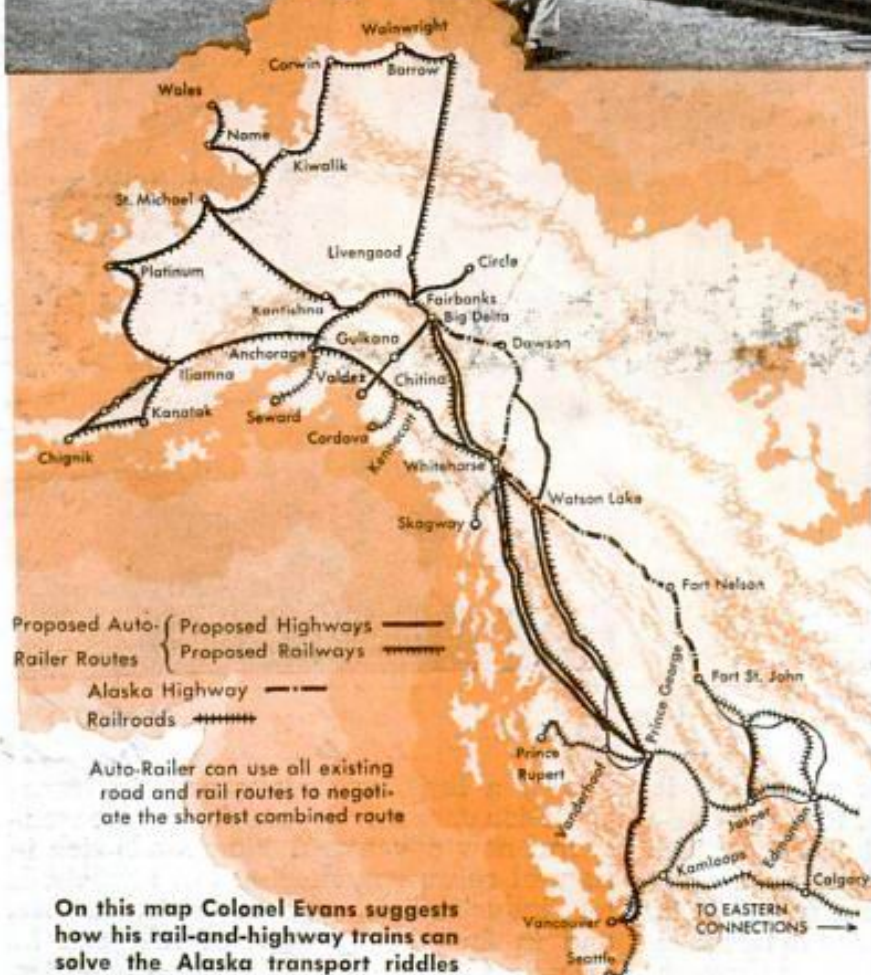
This is not a Buck Rogers dream. These dual road and rail vehicles are in daily use. They have operated millions of miles, on 18 railroads in the United States, Canada and Mexico hauling freight, mail, express, and passengers over steel track and highways.

Here in the marriage of the train and the truck is a new "iron horse" to open up new frontiers.

Alaska is rich not only in coal, but also oil, nickel, tin, asbestos and various other minerals including copper and gold, and has tremendous resources in furs, fisheries,

agriculture and timber. If we can open up this frontier, American youth and American enterprise once more will find wealth in payment for the requisite energies expended.

Alaska is one of the most difficult parts of the world to get into by land. There is no railroad in Alaska with road connections to Canada or the United States. The



road trestle shows a gap of 100 yards. A signal man stops the train at a highway crossing and, without an instant's delay, the train rolls off the track onto the parallel highway, up to the next crossing, beyond the washout, and back on the tracks.

This train is startling. The wheels are rubber-tired; and it has steel retractable flange wheels which, when on the track,

new Alaskan highway built by the Army is at best a semi-pioneer road. This is a rough trail through wilderness with temporary bridges susceptible to two-way traffic only in part, usable when frozen but precarious when thawing. Alaska is a land shut off from the world except by air and sea. Yet it has greater possibilities for development than any part of the Western World.

Billy Mitchell said in 1935: "Alaska is the most central place in the world



Here the rail train of the opposite page leaves the rails for the highway

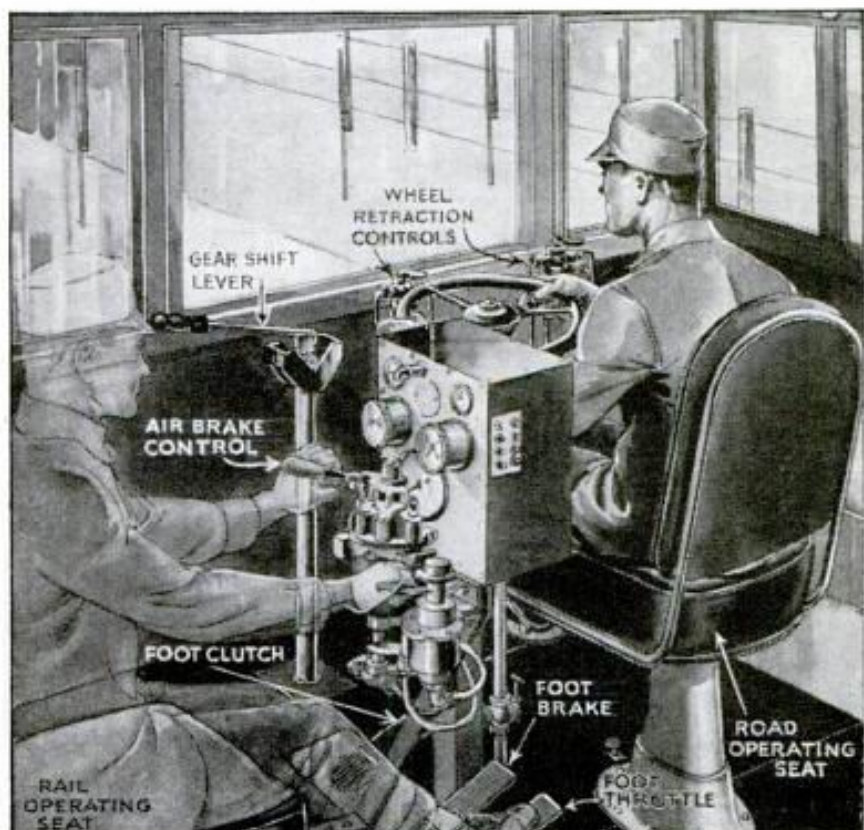


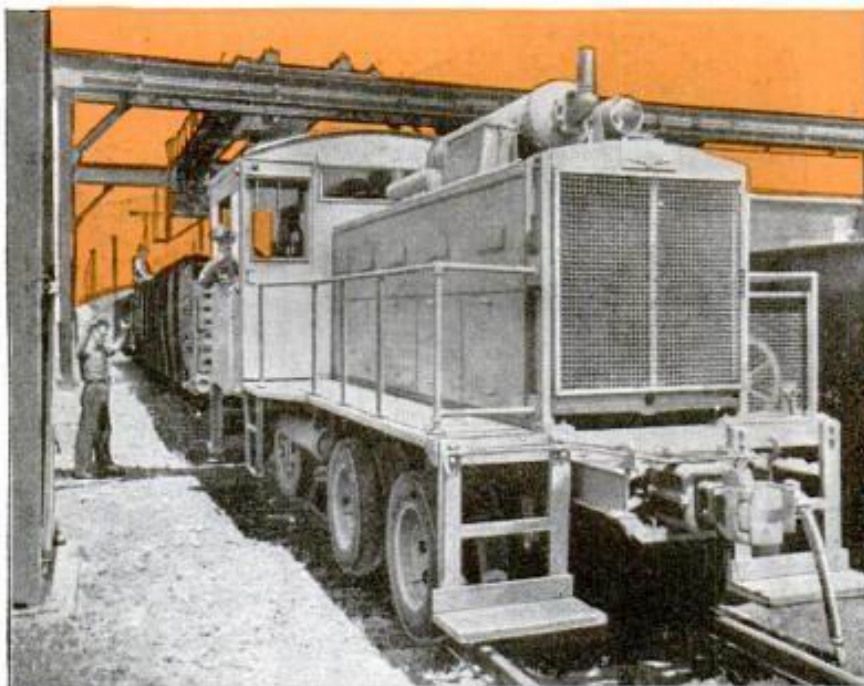
for aircraft and whoever holds Alaska in the future will hold the world. I think it is the most important strategic place in the world."

That this is true from a military standpoint there is no argument. It is also equally true from the standpoint of world industry. If you will take your map, you will see that Alaska is much nearer Europe and Asia, particularly the latter, than are Chicago and New York. Here are some of the comparative distances by air: Chicago to Berlin, 4,500 miles; Chicago to Moscow, 4,500 miles; Chicago to Tokyo, 4,800 miles; Fairbanks to Berlin, 4,400 miles; Fairbanks to Tokyo, 3,500 miles; Fairbanks to Moscow, 4,300 miles.

We have before us a

Above, the "floating" railway over the muskeg. Below, its dual controls



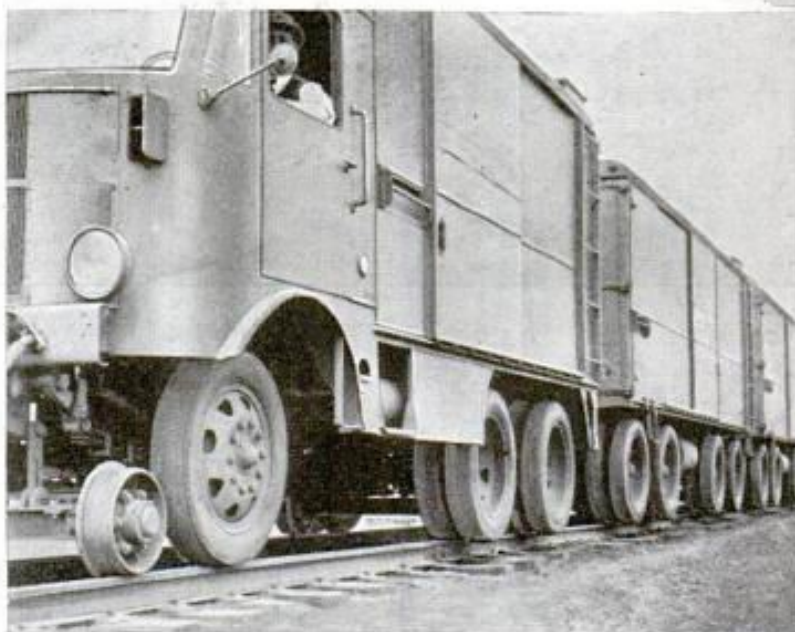


Auto-rail cars in several forms are already in service. Two of them are shown on this page, the pictures revealing clearly how tires ride on steel

world destroyed by war—a world that has to be rebuilt and supplied with everything used by the human race. Alaska can be the “corner general store” for these needy nations. It is the nearest shopping place for American goods and there is room in it for 7 million people instead of the 80,000 normally living there. There is also room in it for billions of dollars invested in industry, commerce, mining. It is the doorway to Russia. And one of these days we will probably see highways and railroads running from Alaska to the center of Siberia and Russia, ferrying across the Bering Straits in summer and by ice tractor in winter.

Great wealth and opportunity are locked within the iron boundaries of this unexplored land. Now, for the first time, there is a key that can unlock the door of Alaska. That key is the auto-railer.

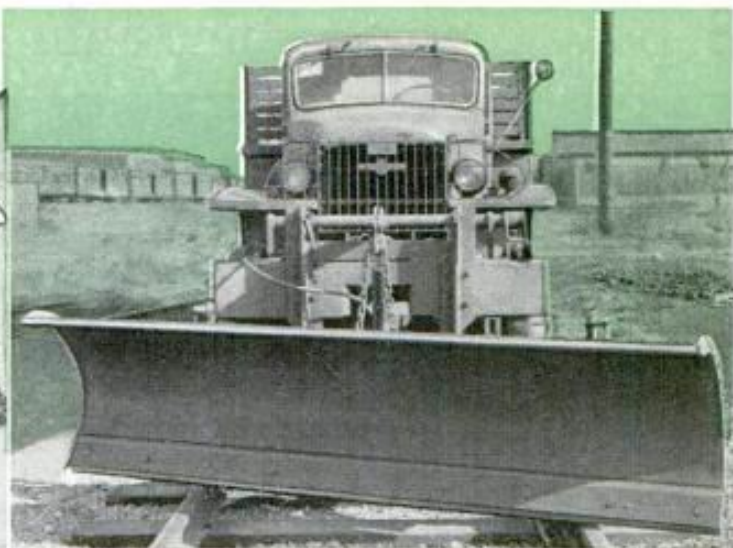
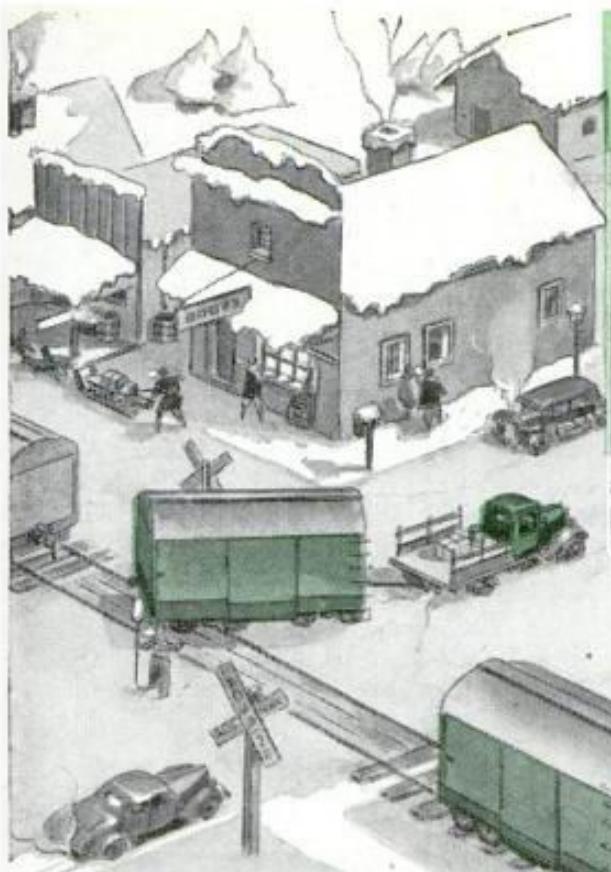
The difficulties of building steam railroads into Alaska in the past have been almost insurmountable. It is a country of deep rivers, great mountain ranges and muskeg. Railroad men have conquered rivers and mountains, but muskeg offers an almost insurmountable obstacle. Muskeg is a peat-like swamp with a bottom of ice. The ice recedes in summer and reaches the surface in winter. It is too hard to drive a pile. And even if the pile was driven and rested on the ice in the summer time, in



another warm summer the pile might sink out of sight.

Our big freight locomotives weigh as much as 300,000 pounds and our loaded freight cars weigh 50,000 pounds or more, each, and the steel tracks and ties with highly concentrated weights and vibration would sink into the quagmire of the muskeg. To avoid the muskeg country for the building of a road would require a long, circuitous route through mountain areas.

Never before has an Alaskan railroad been considered practical. But now the rubber-tired, light-weight, resilient auto-railer train makes railroads possible through undeveloped country. Auto-railers, which run with equal facility on rails

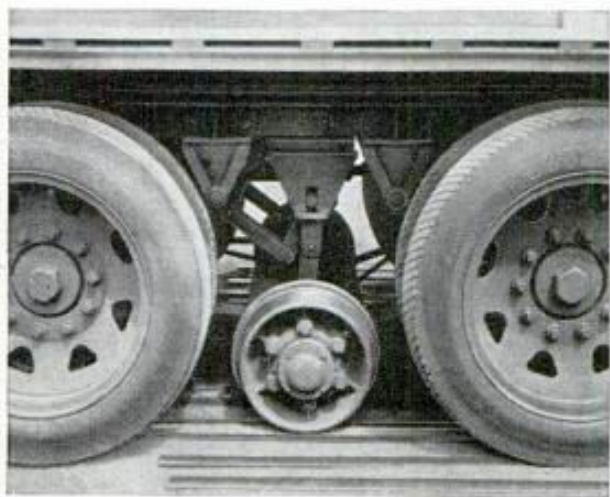


The auto-railer above mounts a snow plow which could function on railroad or highway. At left, a string of the lightweight freight cars arrives in an Alaskan outpost and sets out a boxcar, which is hauled away to its consignee by a local trucker

and roads, will negotiate 30-degree curves and climb 10-degree grades; they are even more efficient than steam or Diesel-electric railroad equipment; they are about one-third as heavy and can be successfully operated on channel steel or wooden rails hewn from the local timber.

Now don't scoff at the idea of wooden tracks, as they are the first kind of tracks used by railroads in this country. They had

This closeup shows arrangement of the pilot truck



metal straps on top to support steel wheels, and there were only single rails. But with dual tires on auto-railers a double track can be used. As the auto-railer locomotive and all of the cars operate on rubber tires, there would be no wear to speak of on the wooden rails and tires and track would last indefinitely.

In the muskeg country a corduroy road made of 24-foot trees 12 inches in diameter can be laid on top of the muskeg, and the wooden rails laid on top of them. They would act like a pontoon bridge floating successfully under the lighter weights of the auto-railer trains—creating, in effect, a "floating" railroad. Relatively light wooden trestles can be quickly erected in rough terrain for inauguration of auto-railer train service; to bridge a river or stream, wooden railroad tracks can be laid on pontoons.

Whereas heavy trains cannot be operated

(Continued to page 160)

The Panama Canal lies open and exposed to attack by modern bombers. Ships wait in line for their turns to thread its outgrown passage from sea to sea. A Chilean engineer proposes a solution to the growing problem:

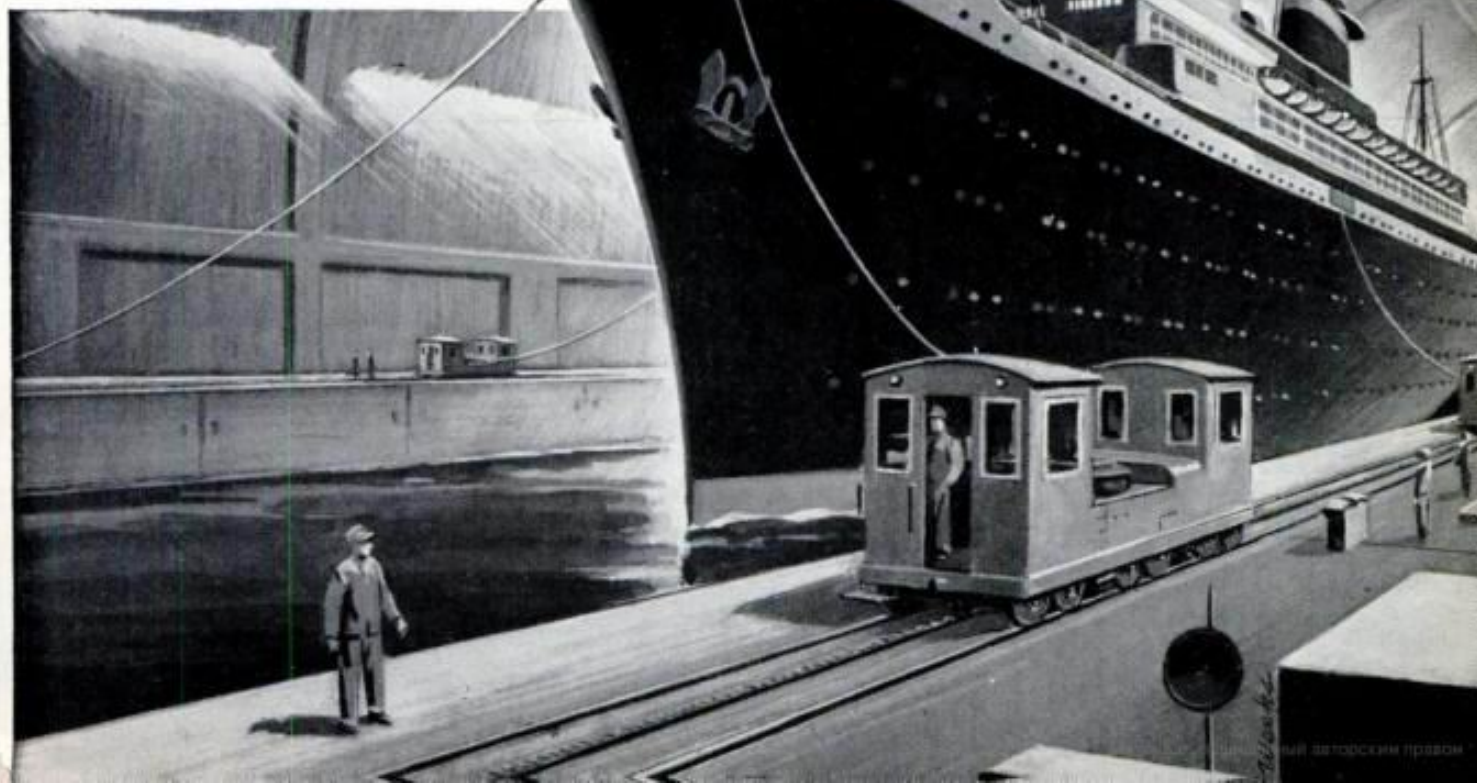
WHY NOT BUILD A TUNNEL FOR SHIPS *From Atlantic to Pacific?*

By Jorge Cortinez Delfino

Engineer, State Collective Transportation Company, Chile

AT THE TIME the Panama Canal was built it was a tremendous engineering project. Planners expected the Canal to serve the needs of shipping for all time. The locks were built 1000 feet long and 110 feet wide in the belief that they would handle any ship ever built.

Today there are several merchant vessels afloat that are too large to pass through the locks. In addition, there are several ships in the United States Navy that cannot pass through the Canal, and others are under construction or planned that will be much too large to navigate the waterway. This severely restricts the military use of the Canal, the purpose for which it was built. Also,





TO ATLANTIC OCEAN

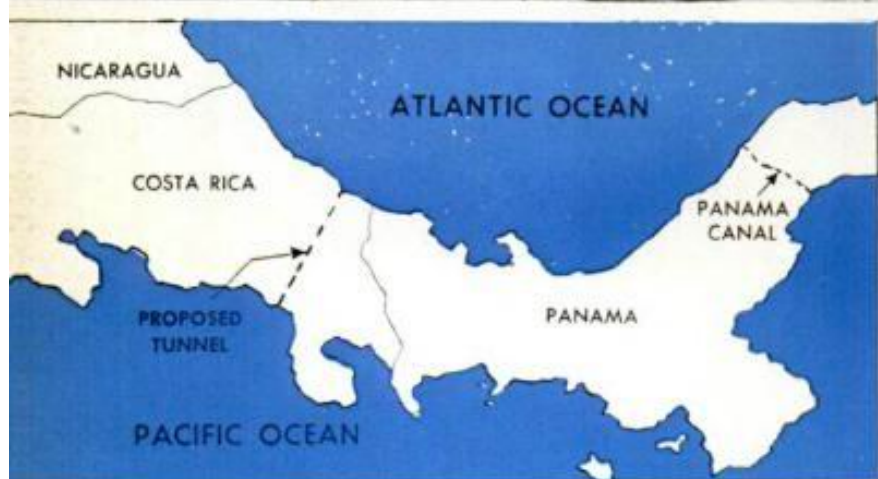


RAILROAD TUNNEL

CONNECTING
CATWALK

PACIFIC-BOUND SHIP

AIR INJECTOR



Tunnel would stretch across narrowest part of Costa Rica. One canal would carry traffic each way. In center would be a railroad tunnel which, during construction, would carry away excavated material

Weeks

the Canal is difficult to protect from air attack.

One other factor to be considered is the tremendous flow of traffic through the Canal. Ships now may wait for days for their turns in the locks.

What can be done to solve these problems? Several proposals have been under study for years. Under one plan, additional and larger locks would be built at some distance from the present ones. However, this project would result in certain navigational hazards because of unavoidable sharp turns in the new channel. Also, the Canal would be as open to enemy attack as it is as present.

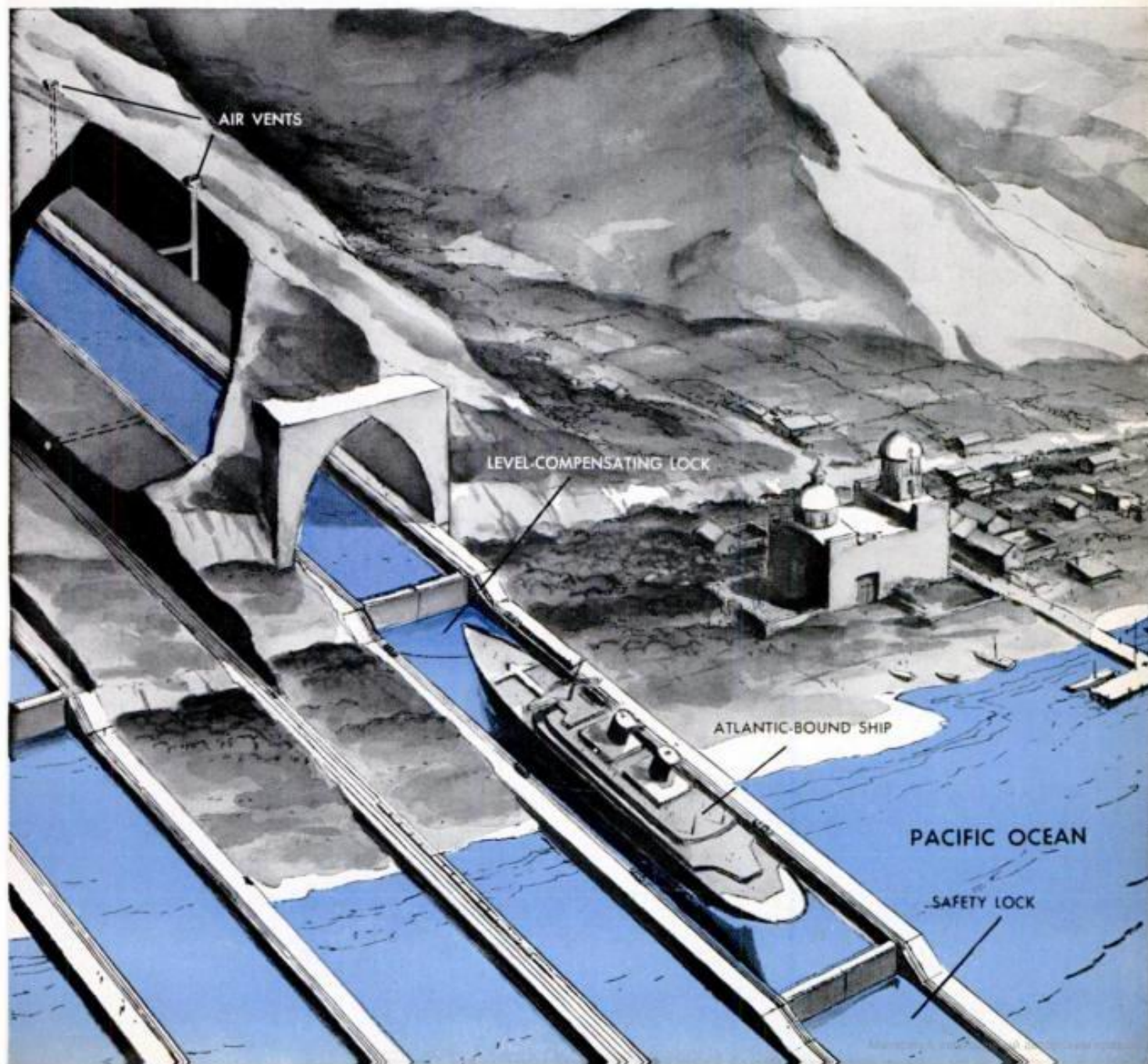
Another proposal is to convert the Canal into a sea-level one. In this case, all locks would be eliminated except for a small tidal lock which would control the differences between the tides in the Atlantic and Pacific. This would reduce the upkeep and permit more ships to negotiate the Canal. However, it would require the construction of many miles of dams to divert from

the Canal the torrents of water during the rainy season. And again the Canal would be relatively open to enemy attack.

New Sea-Level Canal

A brand new sea-level canal somewhere on the isthmus of Central America would solve many of the problems. Several studies have been made of possible locations. Sites have been suggested across Nicaragua, Mexico and another area of Panama. Such sea-level canals, regardless of their location, still do not solve the problem of enemy attack.

My Chilean compatriot, Roberto Gomez Alvarez, and I have proposed a plan which we feel will solve all the problems of ship transit between the two oceans. This plan has been studied and approved by engineers and topographers of recognized standing in the Western Hemisphere. United States Army and Navy engineers have also studied the proposal, and it has been called to the attention of the United States Congress.



JUNE 1956

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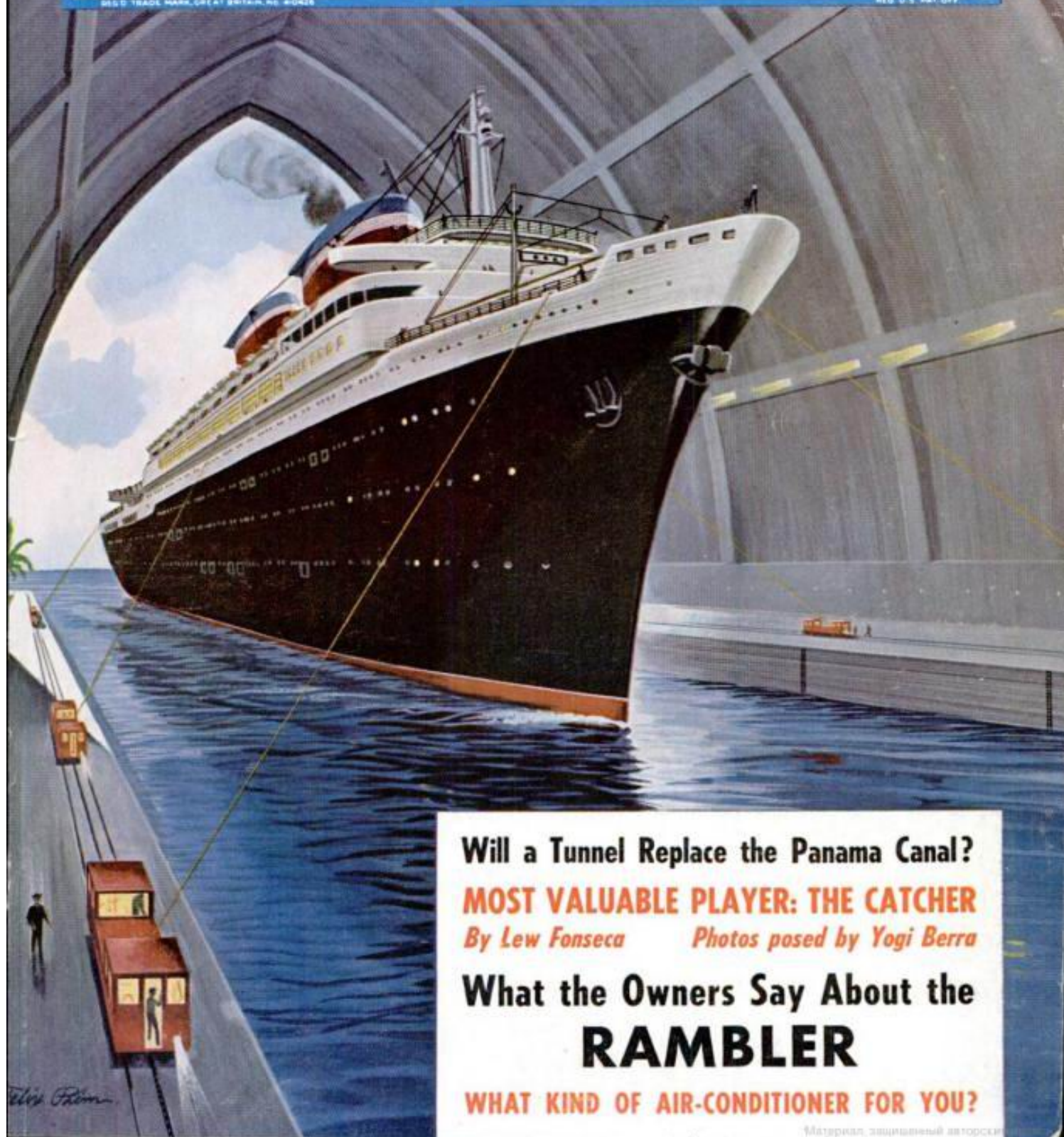
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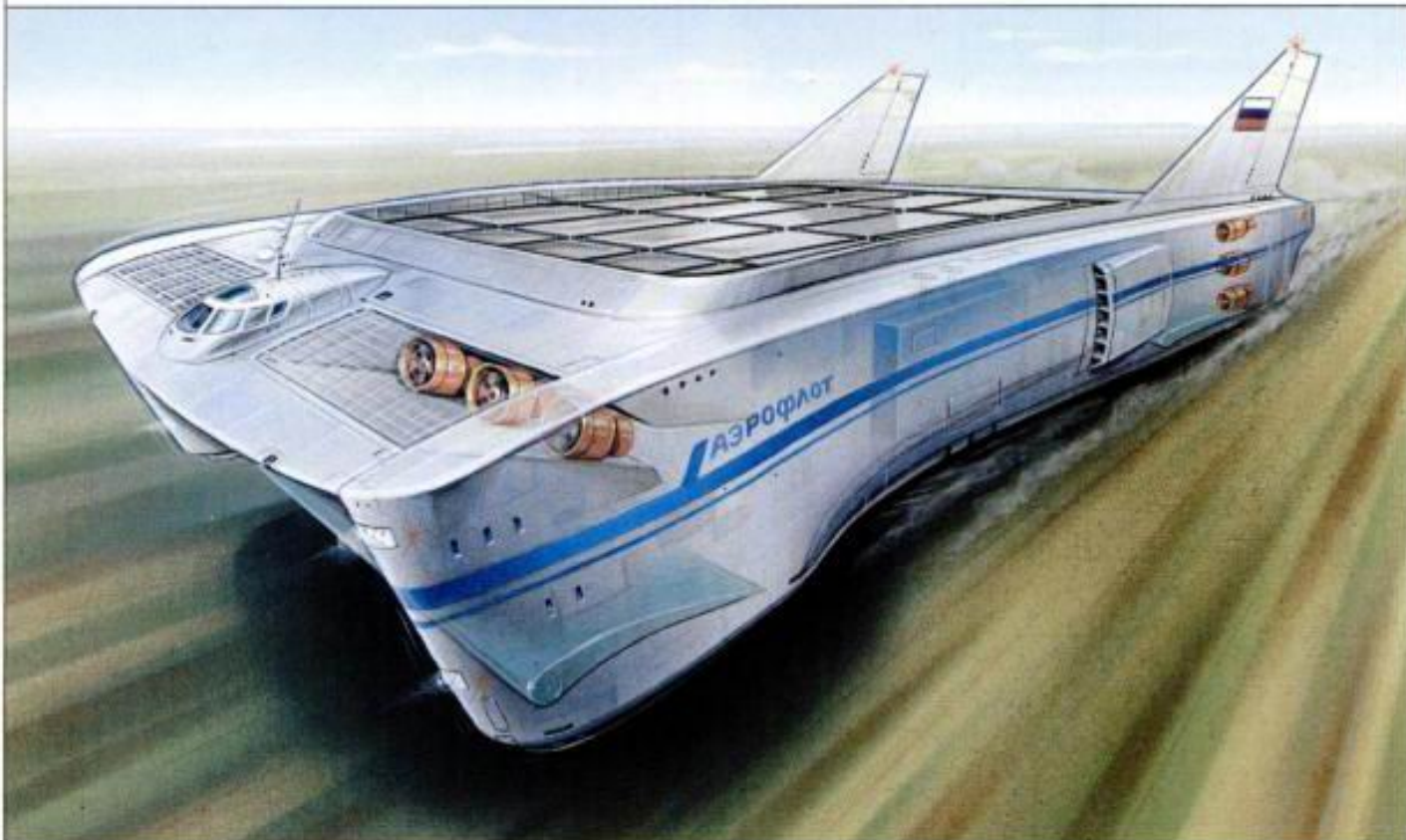
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TECH UPDATE

News Of Tomorrow's Technology Today



PM ILLUSTRATION BY JEFF MANGIAT

Ground-Effect Goliath To Thunder Across Tundra

TAGANROG, RUSSIA—A vast featureless plain sweeps from Murmansk to the Bering Strait, cutting off Russia's Arctic seaboard from the rest of the nation. This ocean of land could be the proving ground for a mammoth wing-in-ground-effect (WIG) transporter that skims equally well over flat lands or water.

WIG researchers in Russia and the United States are calling such a vehicle a triplane, since it would gain lift from three airfoils. Two would span the twin lower hulls, while the upper deck would function as a third foil.

A pure ekranoplane (see "Wingships," page 35, May '92), the machine couldn't fly out of ground effect. Instead, it would barrel along at 40 ft. above the surface.

Twelve turbojets would

deliver the power to move the 4000-ton vehicle, which would stretch 408 ft. long and 166 ft. across. Cruise speed: 300 mph.

In Russia, the machine wouldn't hurtle at will over the frozen plains, but would stick to surveyed tracks laid out with navigational beacons. Elsewhere, the triplane could negotiate the Negev desert, the salt flats of Nevada, Canada's tundra and other similar environments—and skim across the water as well.

A.N. Panchenkov, a follower of the late Italian-born Soviet designer Roberto di Bartini, conceived the craft to resupply Arctic military bases and merchant-marine ports. But it could also ferry

imported freight from Russia's Pacific ports to Eastern Europe, supplementing the Trans-Siberian Railroad. Added impetus for its development may come from the new Russian government's desire to tap the natural

Transtundra Express would fly at 300 mph on three airfoils in ground effect.

resources of the tundra.

Small-scale prototypes, roughly 70 ft. long, have already flitted across Russia's Lake Baikal.

Highlights This Month

- **That's Mr. Atlas To You**—The veteran rocket's new muscle.
- **Reversal Of Fortune**—Smart trailer backs around corners.
- **King Of Rulers**—Machine will measure atomic distances.
- **The Wrath Of ARES**—Rutan's fighter shows off firepower.
- **Cooking With Gas**—Drag car's alternative fuel.
- **Wasteland Warrior**—Huge robot arm fights our toxic Cold War legacy.

Editor: Abe Dine
Assistant Editor: Greg Pope
Contributors: Philip Chen, Mike Dillon



Early conceptual design study for a 10-million-pound wingship is one of several developed by Stephan Hooker for the Pentagon.

1960s, that one-of-a-kind vessel was powered by 10 turbine engines and was about 300 ft. long, making it one of the largest aircraft ever built.

In Alekseev's designs, lift comes from a stubby, low-aspect-ratio wing mounted amidships and a large, horizontal tail surface mounted high atop the vertical fin. This twin-wing configuration overcomes longitudinal instability that has plagued other ground-effect vehicles. The problem arises from a tendency for the center of pressure supporting the craft to move fore and aft with changes in altitude. Alekseev locates the tail surfaces high enough out of ground effect and shapes them so that these complex dynamics aren't a problem.

In the case of *Orlyonok*, the high vertical tail also provides the perch for a Kuznetsov NK-12 turboprop engine, well known to NATO for its use on the Bear strategic bomber. Fitted with twin counterrotating propellers, it puts out 15,000 horsepower to drive *Orlyonok* in cruising flight, during which the forward PAR engines are usually shut down. Not only is the turboprop more efficient than a jet, but its variable pitch provides remarkable low-speed maneuverability in PAR mode.

What is it like to fly such an unorthodox craft? Valentin Vassilyevich Nazarov, chief designer with the Ekolen design bureau and one of *Orlyonok*'s test pilots, spoke to us about it by phone from St. Petersburg, Russia.

"The procedure is similar to the one of any flying device," he says. "You have to start the engines, place all the crew in their places, run a check on all the equipment, warm the takeoff engines and the main engine. Then the

takeoff engines start pumping the air under the wing, and the horizontal movement starts. The craft starts to lift itself from the water. It gains speed up to 150 kmph [93 mph]. Thereafter, the pilot can use all aerodynamic surfaces to fly the craft." Normal cruising altitude is between 25 and 40 ft., depending on wave height.

Some of the strain of maintaining altitude so precisely is relieved by a computerized flight control system, which uses inputs from surface-scanning Doppler and conventional radars. To avoid obstacles, altitudes of up to 5000 ft. are attainable—but at a high cost in efficiency.

Going commercial

While remarkable in many ways, *Orlyonok* represents the past rather than the future of wing-in-ground-effect flight. "*Orlyonok* is already history," says Nazarov. Strapped for cash, but full of ideas, Ekolen has already designed a whole range of new civilian ekranoplanes to replace it.

According to the bureau's president, Ilya Lvovich Gerlozin, these represent a distinctly different approach. "I would use just one word to describe it: comfort. In *Orlyonok*, there was no such thing as comfort because it used to be a military vehicle." Neither Nazarov nor Gerlozin would discuss details of the new craft, elements of which they say are now being patented.

Ekolen's efforts represent just a small portion of the ekranoplane activity now emerging from secrecy in the former Soviet Union. Another, far larger consortium is also known to be carrying on Alekseev's work. Also, a substantially different, but similar-

ly refined, approach is reportedly being pursued by the followers of the Italian/Soviet designer Roberto di Bartini. Their efforts could lead to vehicles suited to travel over the barren tundra of Siberia, as well as over water. However, no Russian company has the resources to undertake a major building program on its own. All are looking for foreign partners.

Wingships: the next wave

One American keenly interested in pursuing such a relationship is Stephan Hooker. His engineering firm, Aerocon, has been commissioned by the Pentagon's Defense Advanced Research Projects Agency (DARPA) to explore the potential of wing-in-ground-effect flight. The hope is that it may turn out to be a technology of considerable military and economic value to the United States.

The upshot of Hooker's thinking is that if WIGs are to be practical as long-range transports, they will have to be big—very big. Typical of the early conceptual design studies he is working with is a 500-ft.-long craft, weighing 10 million pounds. He calls this class of vehicle a "wingship."

Initially, the idea of building a flying machine roughly 10 times the size of the largest airplane on Earth seems outlandish. But Hooker's arguments are logical. They begin with economics. "If you're a Boeing commercial airplane designer, cents per seat-mile is your big thing," he says. This consideration has kept the pressure on to build steadily larger aircraft. As the progression continues, however, the demands of aerodynamics and structural integrity begin to clash. Aerody-

(Please turn to page 123)

AMERICA'S NUCLEAR FLYING SAUCER

A trail of secret documents reveals the startling truth about the U.S. Air Force's flying disc aircraft.

BY JIM WILSON, Illustration by Tom Freeman



► In 1949, the biggest black hole in the universe wasn't in space, but across the Bering Strait. Stretching across 12 time zones, the Union of Soviet Socialist Republics was, as Winston Churchill would so memorably describe it, "a riddle wrapped in a mystery inside an enigma." The few things that most people knew about life behind the Iron Curtain seemed to be pieces of an incomprehensible puzzle. For the handful of intelligence experts who saw how the pieces fit, the "workers' paradise" presented a clear and present danger

COVER STORY

to the American way of life. What the intelligence community knew, and most people did not, was that in the final frantic hours of World War II, the Soviet army had hastily raided Germany's most advanced weapons research laboratories. And, on Aug. 29, 1949, only four years after Hiroshima, the technological booty from those raids turned a country whose farmers still used horse-drawn plows into a nuclear superpower.

The fireball of the communist atomic bomb cast a

sinister new light on an event that previously seemed quite inconsequential. In the summer of 1945, an unusual rumor had begun to circulate within the intelligence division of the European Command. During interrogations, captured German aircraft engineers referred to an extraordinarily fast rocket plane under development at a secret base in Bavaria. Unlike the Messerschmitt Me 163 rocket planes that had begun to attack Allied bombers in the last months of the war, this aircraft had an odd-looking curved wing that blended into its fuselage. The aerodynamic advantage of this configuration had been known to American designers for more than a decade. It created more lift than a standard wing, especially at low speeds, and provided more internal capacity for carrying bombs. In the early days of the war, the U.S. Navy had briefly experimented with circular wing design for those very reasons.

Anticipating that the first generation of communist atomic bombs would be as heavy as those America had dropped on Japan, it seemed reasonable to U.S. defense planners that the Soviet air force, which then lacked a nuclear bomber, would try to adapt German disc tech-



From 300 miles in space, the LRV would be able to rain nuclear destruction on the Soviet Union, Red China and North Korea.

"The operational mission design is six weeks at an orbital altitude of 300 nautical miles."

nology. The United States was, after all, doing exactly the same thing with the V-2s and Nazi rocket scientists it had spirited away in Operation Paper Clip.

In our July 1997 cover story, "Roswell Plus 50," **POPULAR MECHANICS** detailed how Air Force interest in duplicating Nazi technology led to two American flying disc projects. Project Silver Bug sought to build a vertical take-off and landing aircraft. Project Pye Wacket was to create small discs for use as air-to-air missiles. Documents declassified since then point to a third secret project, a 40-ft. "flying saucer" designed to rain nuclear destruction on the Soviet Union from 300 miles in space.

The official designation for America's nuclear flying saucer was the Lenticular Reentry Vehicle (LRV). It was designed by engineers at the Los Angeles Division of North American Aviation, under a contract with the U.S. Air Force. The project was managed out of Wright-Patterson Air Force Base, in Dayton, Ohio, where German engineers who had worked on rocket plane

and flying disc technology had been resettled.

The LRV escaped public scrutiny because it was hidden away as one of the Pentagon's so-called "black budget" items—that is, a secret project that is incorporated into some piece of nonclassified work. On Dec. 12, 1962, security officers at Wright-Patterson classified the LRV as secret because: "It describes an offensive weapon system." The project re-

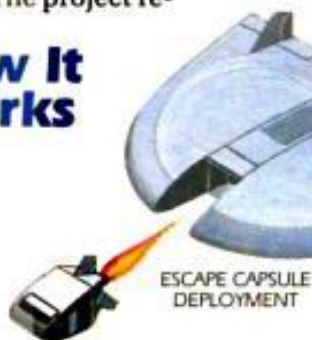
on orbit. There are repeated references to the LRV launching weapons-carrying clusters.

A considerable part of the design study focuses on the details of building a 40-ft.-dia. airframe and strengthening it against the acceleration of 8 g's and wind shear it would experience during launch. However, no mention is made of the type of booster the disc would ride into space.

Most likely, the LRV would have flown atop a multistage rocket, like the Saturn booster used in the Apollo moon program. The engineering study, however, suggests a more intriguing possibility. At some point, the LRV could have been powered by one of the nuclear rockets then under development by the Air Force and the Atomic



How It Works



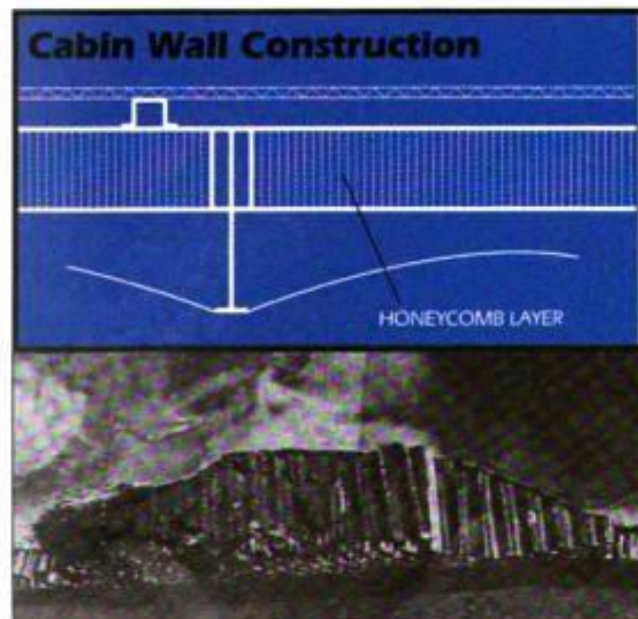
In normal operation, the LRV would use its saucer shape to dissipate re-entry heat and then provide lift for atmospheric flight.

mained classified until May 1999, when a congressionally mandated review of old documents changed the project's status as a government secret, downgrading it to public information. The Department of Defense did, however, successfully seek to have the document's distribution restricted to defense contractors. PM obtained its copy as the result of a Freedom of Information Act request.

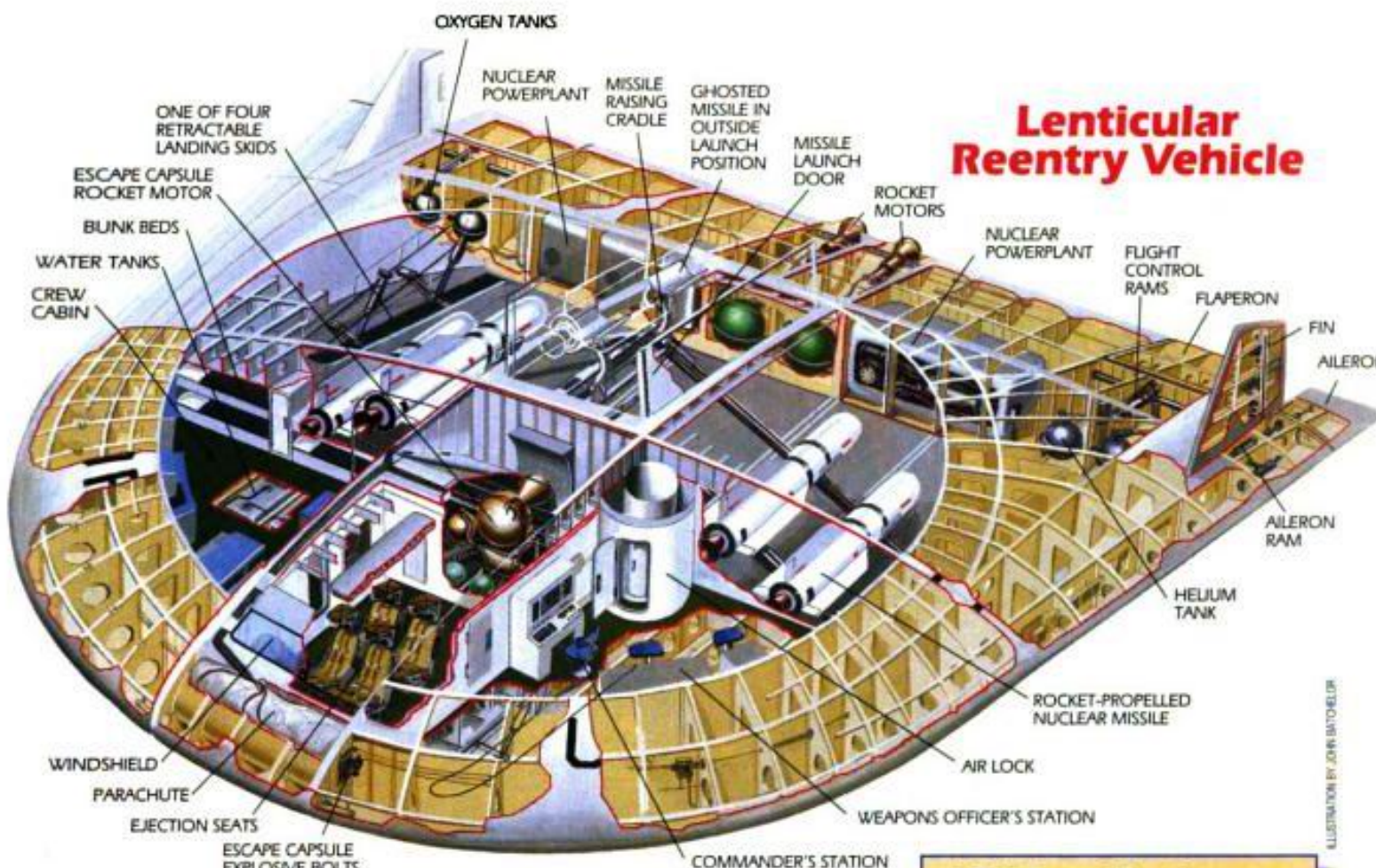
Inside The LRV

"The operational mission design is six weeks' duration at a nominal orbital altitude of 300 nautical miles, with a crew of four men," according to the report. The weapons bay would hold "four winged weapons" that could be either launched or detached and parked

on orbit. There are repeated references to the LRV launching weapons-carrying clusters. A considerable part of the design study focuses on the details of building a 40-ft.-dia. airframe and strengthening it against the acceleration of 8 g's and wind shear it would experience during launch. However, no mention is made of the type of booster the disc would ride into space. Most likely, the LRV would have flown atop a multistage rocket, like the Saturn booster used in the Apollo moon program. The engineering study, however, suggests a more intriguing possibility. At some point, the LRV could have been powered by one of the nuclear rockets then under development by the Air Force and the Atomic



The materials recovered from the Fraser farm bear a striking resemblance to LRV engineering drawings.



Alamos, N.M. A DOE spokesman told PM that the only reason these records would have remained classified was if they dealt with an operational military system.

The four-man crew would ride a wedge-shaped capsule built inside the LRV. The capsule would divide the front portion of the disc into separate work and off-duty areas. The nuclear-tipped rockets would be stored in the rear segments.

Although these rockets were not called multiple independent reentry vehicles (MIRVs), they match the description of these multiple-warhead-delivery devices, which were later banned by disarmament treaties. An MIRV-equipped LRV would have been able to eliminate the war-making capabilities of the Soviet Union, China and North Korea at the push of a button.

In normal operations, the capsule would function as the LRV's flight control center. In an emergency, the crew could fire the capsule's independent 50,000-pound-thrust solid-fuel rocket motor and return to Earth. The capsule's final descent would be slowed by a parachute, much like the X-38 "lifeboat" planned for the

international space station now under construction.

A textbook mission would conclude with the entire LRV returning to Earth. It would fire its nuclear or liquid-fueled main rocket to brake, then travel edge-first into the atmosphere. Its disc form would dissipate the heat of re-entry, then act as a wing. Its flattened tail structure would provide directional stability and control. A minute or so before landing, skids would extend and the LRV would settle onto a stretch of dry lakebed.

The engineering study does not describe how the LRV, which would weigh just over 17,000 pounds without its crew, weapons, fuel and stores, would then have been returned to the launch pad. One possibility, suggested by the inclusion of a high-pressure helium storage tank, is that it would have been ferried by a heavy-lift balloon, as shown in the drawing on the opposite page. While the LRV would not have had sufficient helium to inflate a balloon, the tank would have

Lenticular Reentry Vehicle

LRV Specifications

Crew	4
Weapons	4 nuclear missiles
Mission Length	6 weeks
Dimensions	
Diameter	40 ft.
Center	90 in.
Edges	6 in.
Wing	1548 sq. ft.
Weights	
Launch	45,000 lb.
Landing	33,395 lb.
Empty	17,042 lb.
Engines	
Booster	Chemical/Nuclear
Main	Hypergolic/Nuclear
Capsule	Solid fuel
Electric Power	7 kw (thermal nuclear)
Designer	North American Aviation

had sufficient capacity for replenishing the lift-bag to permit trips of several thousands of miles.

In 1997, as part of its effort to debunk the Roswell alien landing myth, the Air Force revealed details of several heavy-lift balloon research projects. Among those were experiments in which 15,000-pound payloads were lifted to 170,000 ft. While not specifically acknowledging the

LRV by name, an Air Force spokesman conceded that during the Cold War it routinely used high-altitude balloons to

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**CUBE: THE
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Popular Mechanics

AIR FORCE'S NUCLEAR FLYING SAUCER

Recently Declassified
Information May
Explain Decades
of UFO Sightings

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CORVETTE Z06**

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Musclecar Shootout

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FURNITURE MAKING
Our Annual Woodworking
Guide Presents 4 Beautiful
Pieces That Will Make An
Impression In Your Home



No Snorkel, No Scuba

ARTIFICIAL GILLS:

They'll Let You Breathe Like a Fish

Newest underwater breakthrough 'filters' oxygen from water

By WALLACE CLOUD

Illustration by Dale Gustafson

CAN MAN BREATHE like a fish? Why not? Talk to a few of the people who are working on the problem, and what once seemed incredible suddenly seems obvious: A diver doesn't have to carry air tanks—he can get oxygen from the water around him.

Like other science writers, I was a bit skeptical a few years ago when Commandant Jacques-Yves Cousteau, co-inventor of the aqualung, predicted divers would become "men-fish," *breathing water*. He claimed, also, that it would soon be possible to plug an "artificial gill" into man's bloodstream. Today, this is what's happening:

- Two American inventors have patented artificial gills that let a diver breathe into his lungs the oxygen that is dissolved in the water, and get rid of exhaled carbon dioxide by the same route.

- These gill systems promise to eliminate or minimize diving problems: the bends, nitrogen narcosis, oxygen poisoning. Conceivably divers will move up and down in the ocean as freely as fish, without decompression stops.

- Scientists now talk seriously of circulating the diver's bloodstream through a gill unit, bypassing the lungs. Two divers for an undersea-engineering firm have volunteered to undergo surgery necessary to implant such a device.

- The same kind of gill system can be used to supply fresh air in submarines and undersea stations.

When Cousteau, in 1962 predicted gills for men, he could not have known that one kind of gill had already been tested. The turning point came on Aug. 6 that year, when a Rutherford, N.J., research engineer named Waldemar A. Ayres and his wife went on a secret mission to Jones Beach, N. Y.

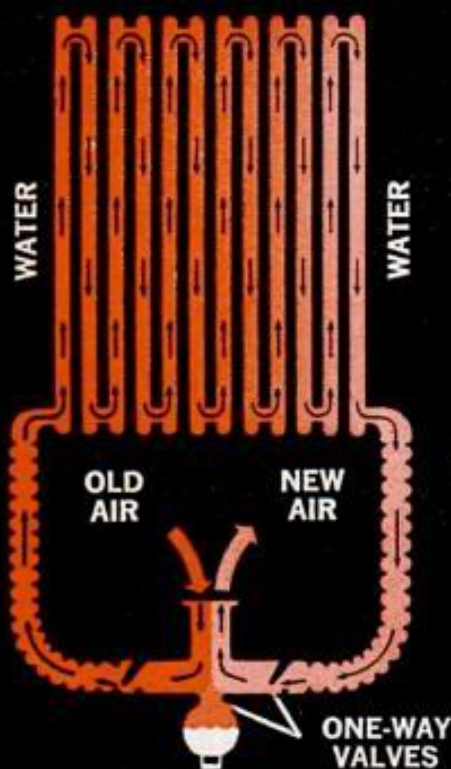
Ayres unrolled four foot-wide strips—actually flat plastic tubes, each 25 feet long—and carefully inspected them. (One side of each tube was made of fragile material.) He interconnected them with short lengths of garden hose and hooked up a scuba diver's mouthpiece. Valves at the mouthpiece were arranged so his exhaled breath would travel the entire combined length of the tubes, then be reinhaled.

He floated the tubes on the water, fragile side down. Then he sat down in the water, clamped his nostrils shut with a clip, put the mouthpiece in his mouth and proceeded to inhale and exhale through the apparatus for an hour and a half as it bobbed up and down on the waves. He stopped only when water leaking in made it hard to force his breath through the tubes.

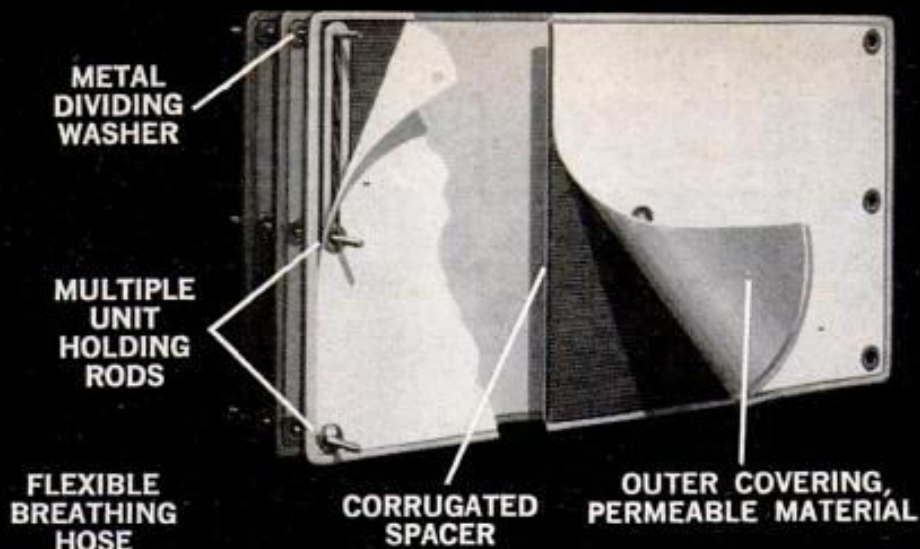
Wally Ayres thus became the first human to successfully breathe dissolved oxygen from the water like a fish.

How could he be sure? The top side of each tube was made of tough, airtight upholstery vinyl. No oxygen could get in from that side. But the side immersed in water was a spongy polyethylene

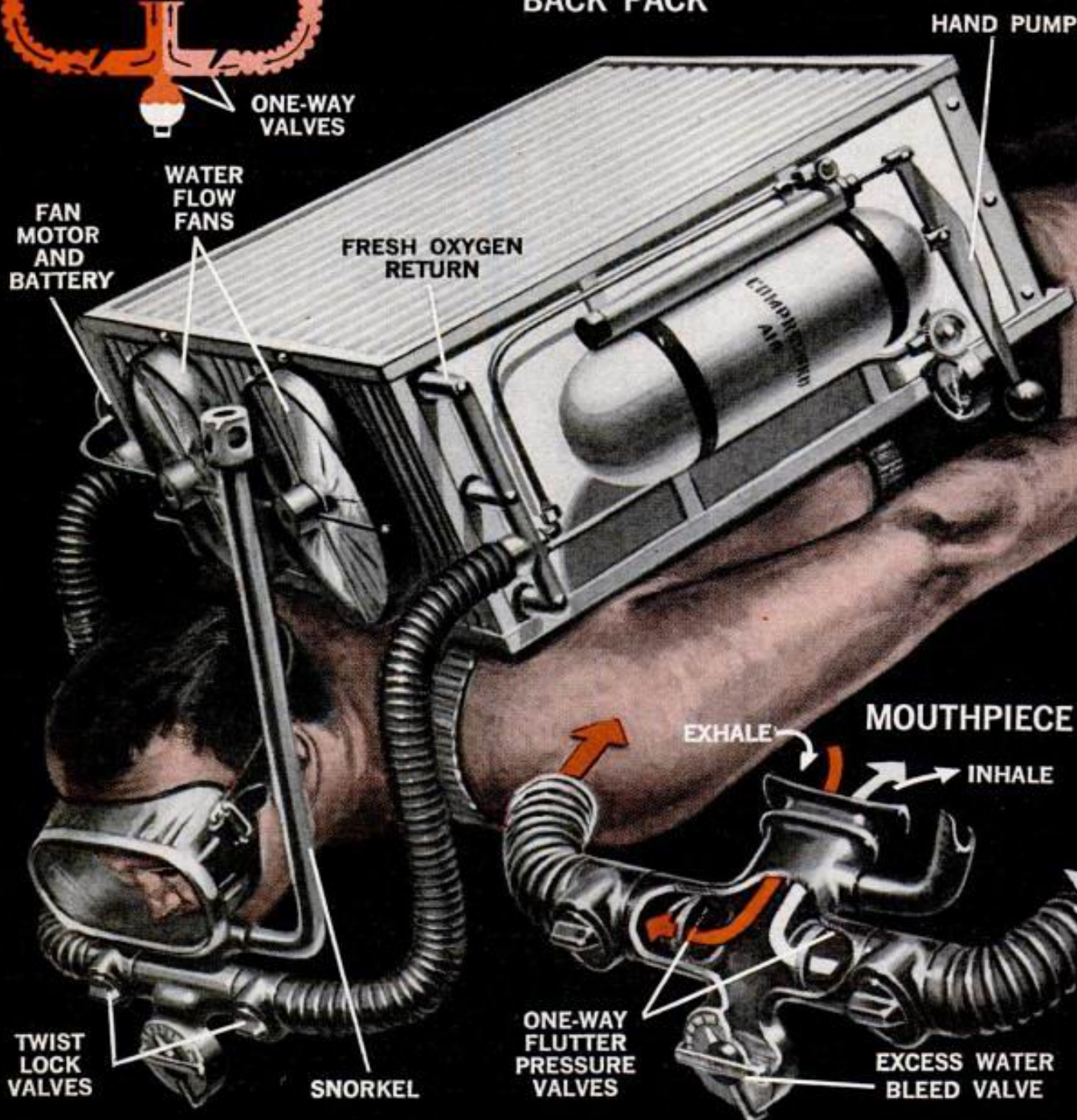
OXYGEN-CO₂ EXCHANGE CYCLE



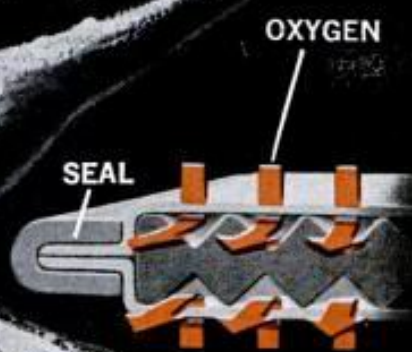
GILL MEMBRANE



BACK PACK



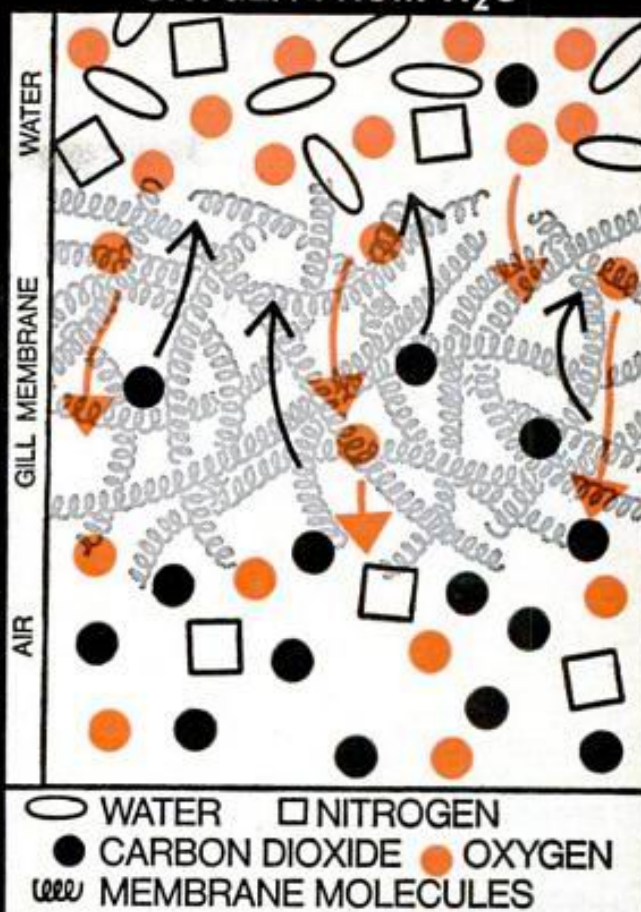
CROSS SECTION OF GILL



TWO-WAY STREET: Molecules of gas can go in either direction between larger molecules of the membrane; which way they go depends on "partial pressure"—a larger supply of molecules on one side of the membrane.

Oxygen molecules, more numerous in water than in diver's exhaled air, diffuse into gill through the membrane. There is a larger "population" of carbon dioxide molecules inside the gill than there is dissolved in water, so CO₂ travels out.

HOW GILL SEPARATES OXYGEN FROM H₂O



material—containing millions of microscopic pores—designed originally for baby pants. Through this membrane, his breath was in contact with the water; oxygen diffused from the water into the air in the plastic tubes, and carbon dioxide diffused from the air into the water.

If it hadn't worked, Ayres would have experienced the symptoms of anoxia and carbon dioxide excess: flushed face, difficulty in breathing. Or he could have passed out in minutes.

The next day Ayres repeated the performance while a friend observed, took pictures, and recorded the time. The information was then incorporated into an affidavit. Ayres was in the middle of a 10-year struggle to get the U.S. Patent Office to recognize his invention.

That's the way Ayres told me the story, which he had kept secret during the touch-and-go process of getting the basic patent (No. 3,228,394) on all underwater breathing systems using the gill principle.

He had conceived the idea in 1955, while scuba diving in the Bahamas. After all, he reasoned, there isn't a vast difference between a fish's gill and the human lung. In both cases blood moves past one side of a membrane; on the other side is the oxygen-bearing medium—air or water.

Both gills and lungs work because of "partial pressure." This means that in a mixture of gases, the pressure of each gas is a fraction of the total pressure of the mixture. That fraction—the partial pressure of a single gas—is proportional to the percentage of the gas in the mixture.

For example: Air consists of about 78 percent nitrogen, 21 percent oxygen and small amounts of other gases including carbon dioxide. Atmospheric pressure at sea level is 14.7 pounds per square inch, so the partial pressure of oxygen in the air is 21 percent of 14.7 p.s.i.

In water exposed to the air, the gases are dissolved in the same proportions;

THE MACHINES OF STAR WARS™

EPISODE I

THE PHANTOM MENACE™

We lift the hood and pull back the access panels on the most amazing land- and spacecraft George Lucas has ever imagined.

BY JIM WILSON, Illustrations by Richard Chasemore and Hans Jenssen

► Crammed into the subway-tight

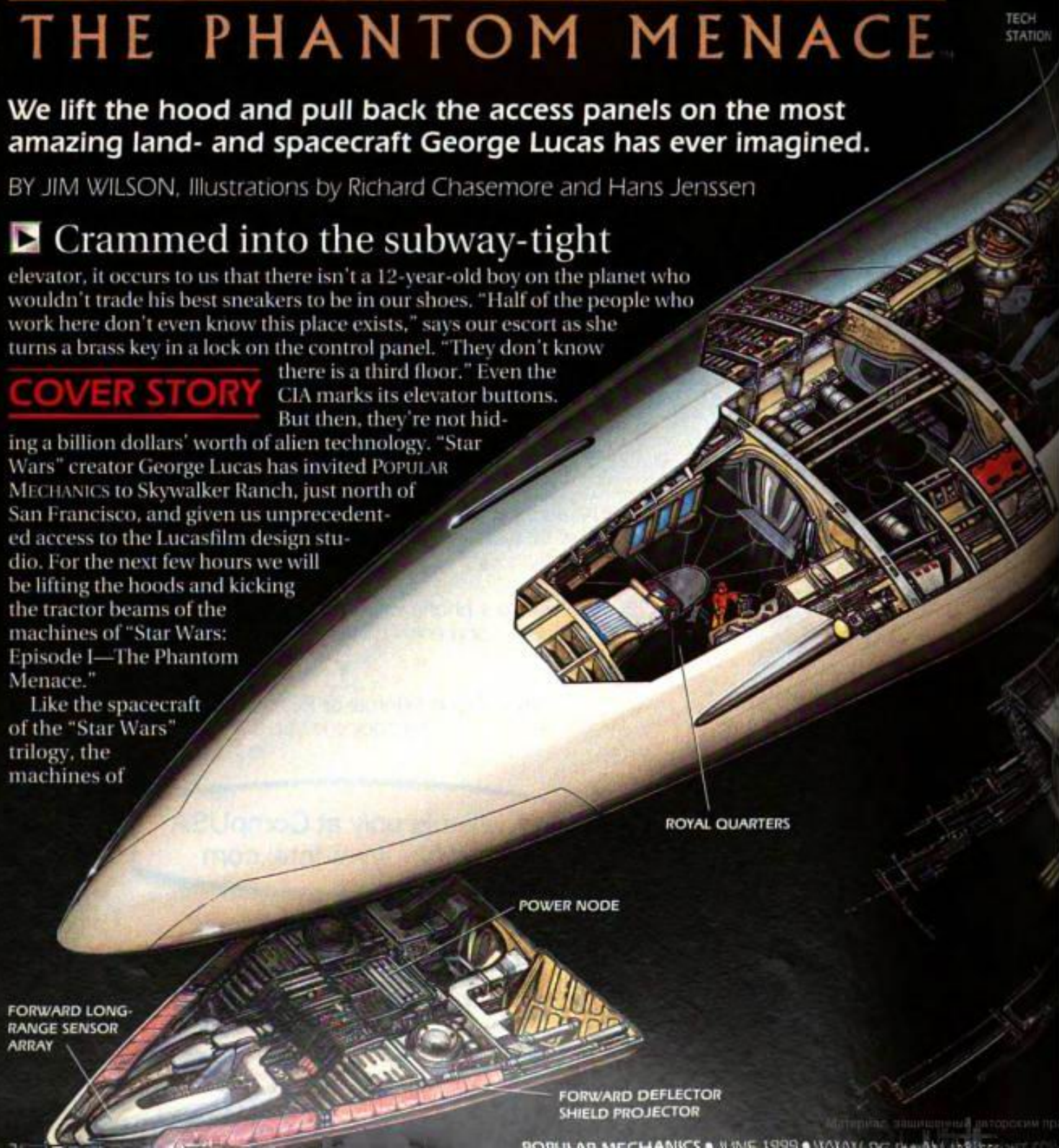
elevator, it occurs to us that there isn't a 12-year-old boy on the planet who wouldn't trade his best sneakers to be in our shoes. "Half of the people who work here don't even know this place exists," says our escort as she turns a brass key in a lock on the control panel. "They don't know

COVER STORY

there is a third floor." Even the CIA marks its elevator buttons. But then, they're not hid-

ing a billion dollars' worth of alien technology. "Star Wars" creator George Lucas has invited POPULAR MECHANICS to Skywalker Ranch, just north of San Francisco, and given us unprecedented access to the Lucasfilm design studio. For the next few hours we will be lifting the hoods and kicking the tractor beams of the machines of "Star Wars: Episode I—The Phantom Menace."

Like the spacecraft of the "Star Wars" trilogy, the machines of



FORWARD LONG-RANGE SENSOR ARRAY

POWER NODE

ROYAL QUARTERS

FORWARD DEFLECTOR SHIELD PROJECTOR

OBI-WAN KENOBI

COCKPIT

QUEEN AMIDALA

ROYAL THRONE ROOM

RADIAL
SUBLIGHT
ENGINE

R2-D2

DROID
HOLD

POWER
CONVERTERS

POWER CORE

DEFLECTOR
SHIELD
GENERATOR

ESCAPE
POD

HYPERDRIVE
CONDUITS

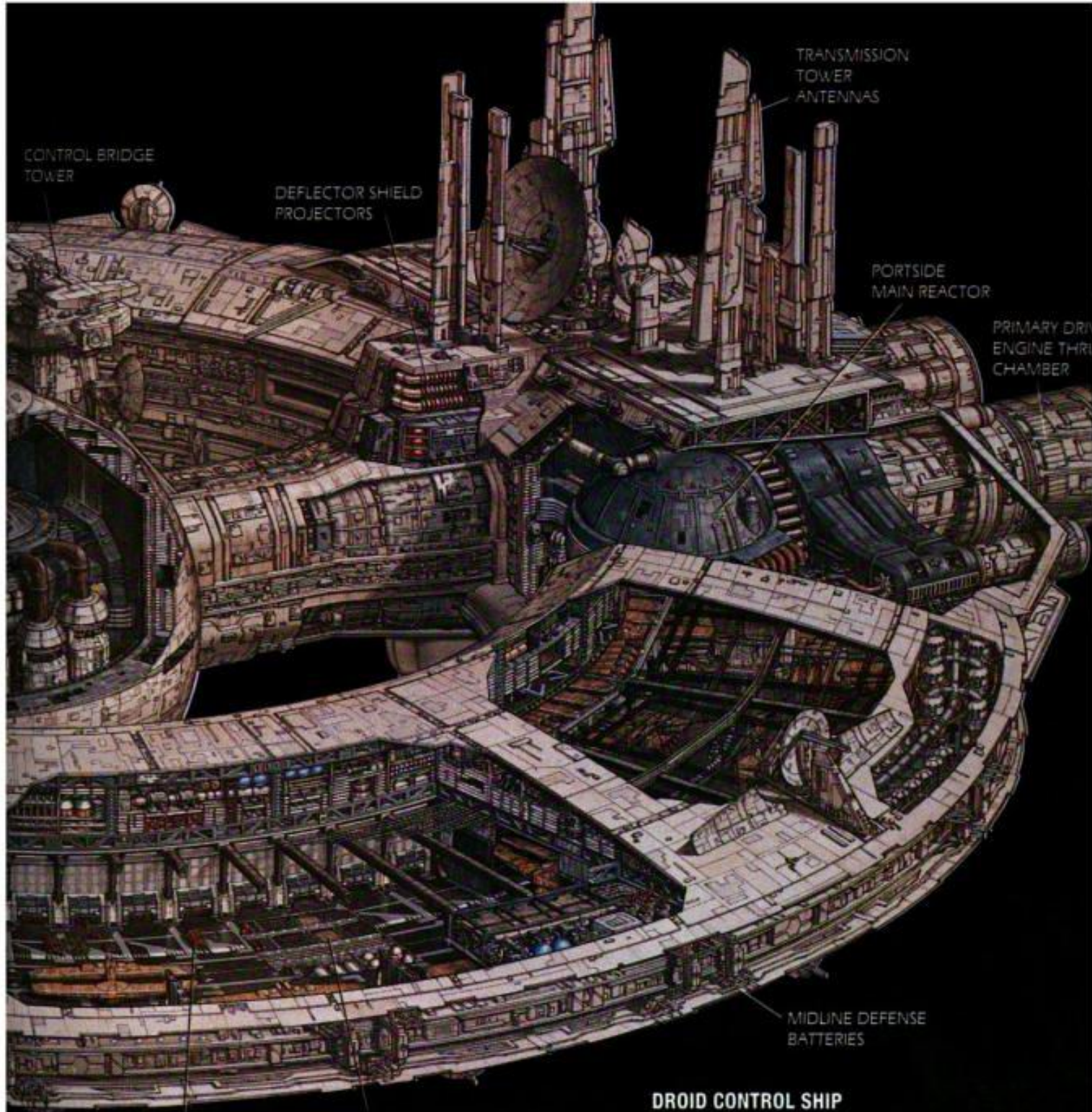
HYPERDRIVE CORE

ROYAL STARSHIP

In an age when droids and automated factories do most of the work, the Royal Starship that carries the Naboo Queen Amidala on state visits distinguishes itself as the epitome of traditional craftsmanship. Even the purely decorative mirror chromium finish is hand-polished. The obsession with detail carries over to the hyperdrive core, which in addition to being a work of precision art, has been tweaked to be one of the best performing systems in the universe.

“As George was writing the story he realized he wanted a battleship that was completely different.”





DROID CONTROL SHIP

MTTs STAGED FOR LOADING

MASSIVE AMMUNITION DUMPS

One of the challenges for Chiang and Reynolds was to create a control ship that fulfilled Lucas's artistic vision, and at the same time supported an action sequence in which Anakin Skywalker moves among the hangar bays where the Landing Ships are loaded with droid-carrying MTTs. "When [Lucas] calls out for those actions on the storyboard, we have to get down to the physics and the reality so that this ship makes sense," says Chiang.

"Episode I" sprang from Lucas's rich imagination. The job of making these impossible vehicles seem as real as the family minivan has fallen upon two young men whose own imaginations were sparked by the first "Star Wars" movies.

"After seeing 'Star Wars,' I wanted to get into special effects and film design," says Doug Chiang, the director of concept design for "Episode I." He is showing us the 7-ft.-tall battle droid in the corner of

his studio on the secretive top floor of the Main House at Skywalker Ranch. Spanning about 30 x 50 ft., the vaulted-ceiling room is plastered with posters from the original "Star Wars" movies and sketches of characters and spaceships from films yet to come. Light pours onto the blue carpet from a massive window. Nearby, a wood-burning stove adds the homey feel of an attic put to good use. In the center of it all is a square table, big enough to seat

the cast of "Beverly Hills 90210" for Thanksgiving dinner. At the moment it is packed tightly with a clan of unearthly figures. Casual though the setting may seem, there is a drill sergeant's orderliness to this place. If Martha Stewart were your mom and Bill Gates your dad, this would be the room where you grew up.

Roads To Star Wars

Creating the stuff of teenage fantasies is anything but kids' stuff. Chiang studied film at the University of California, Los Angeles. "I wanted to be a stunt motion animator," he says as we push aside a platoon of alien critters to make room

R2 UNIT
COMPUTERANAKIN
SKYWALKER

HYPERDRIVE

FUEL TANK

LASER
CANNONPOWER
CELLSTORPEDO
LAUNCHERTORPEDO
MAGAZINEPROTON
TORPEDO

N-1 STARFIGHTER

Although the single-seat N-1 Starfighter has sharp teeth—including a laser cannon and proton torpedoes—its main function is to serve as an honor guard for the Royal Starship, hence its partially chromed finish.

for my notepad. Animators speak in the language of line and color. So Chiang, a talented artist, honed his drawing skills. "It was easier for me to get a job in film through my art." Persistence also paid off.

He started his career as a key animator on the "Pee-wee's Playhouse" television series. By the time he was 37, Chiang had collected Academy Awards for "Death Becomes Her" and "Forrest Gump."

On "Episode I," Chiang worked closely with Lucas to develop almost everything you see except the actors. Sketches and models built in his attic studio were shipped to a second art studio in Leavesden, England, where they were turned into the sets that appear in the film.

Joining us is David West Reynolds, whose cutaways are fea-

tured on these pages and in a forthcoming book titled "Star Wars: Episode I Incredible Cross-Sections" (Dor-

ling Kindersley, Ltd., www.dkonline.com). Reynolds came to the film by a route that is itself the stuff of movies. By training, the 31-year-old is a vertebrate paleontologist and archeologist. He earned his doctorate at the University of Michigan, where he taught briefly.

"It's a natural step, archeology to working on 'Star Wars,'" he kids. In fact, it was, "I had done some work in North Africa, so I was familiar with Tunisia, where the original 'Star

Wars' film was shot and where we later shot 'Episode I.'" He was asked to help relocate the filming site of the original movie. "We went in December 1993 for the first location scout for 'Episode I.' They took me with them as a guide." He stayed with the project, authoring a series of books for "Star Wars" fans.

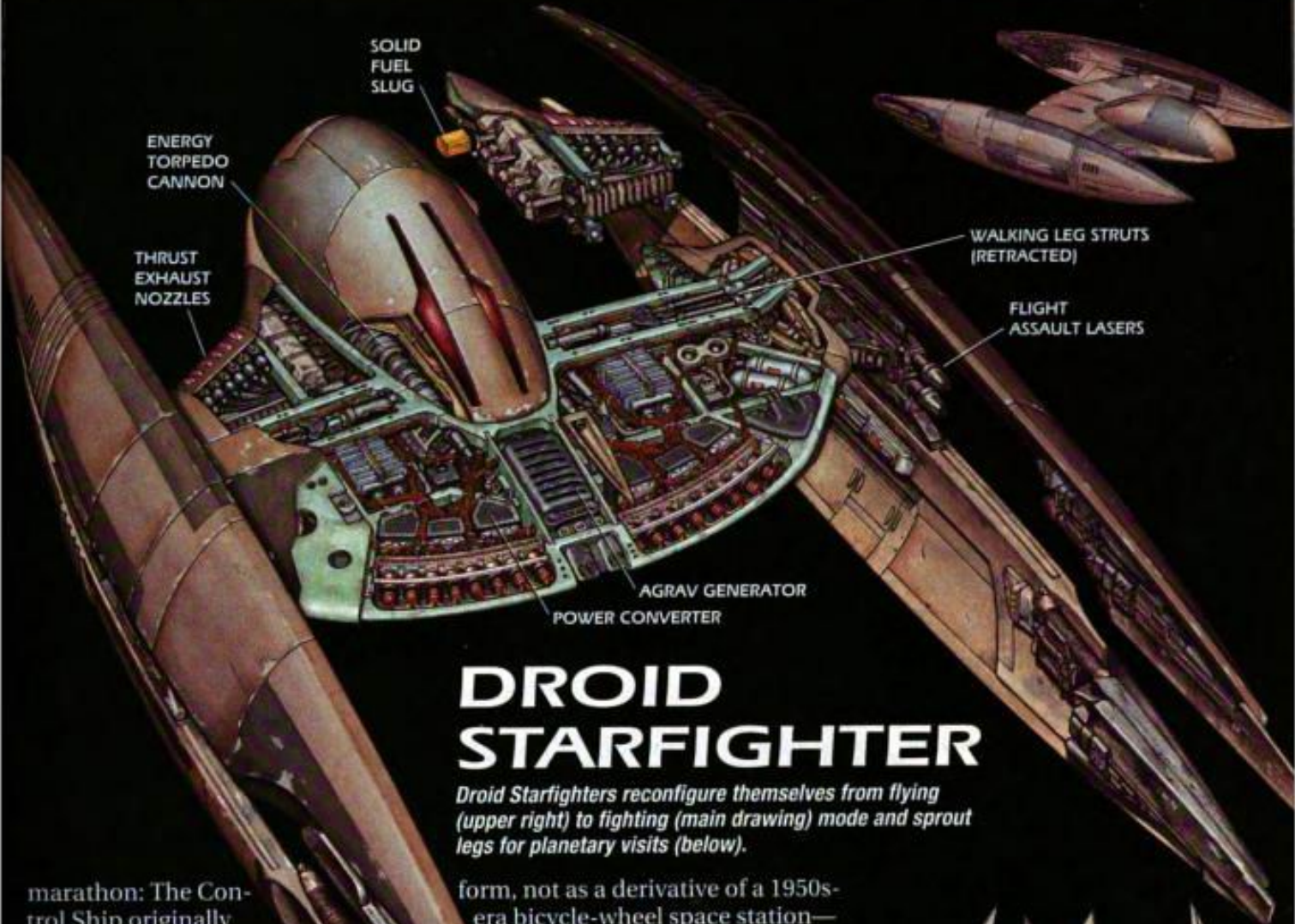
After Lucas and Chiang decided what the machines of "Star Wars" should look like from the outside, it was largely up to Reynolds to make the interiors realistic enough to convince ticket and book buyers to snap on their reality suspenders.

The Control Ship

While Chiang and Reynolds don't need to observe the laws of physics as rigorously as NASA's rocket scientists, getting all the parts of an imaginary spacecraft to fit together can sometimes be just as challenging. And nowhere was that task as daunting as in the creation of the Droid Control Ship. For sheer size and drama it is the most spectacular craft in "Episode I."

Chiang casually tosses out a fact that is sure to be the tiebreaking answer in a future "Star Wars" trivia





ENERGY
TORPEDO
CANNON

THRUST
EXHAUST
NOZZLES

SOLID
FUEL
SLUG

WALKING LEG STRUTS
(RETRACTED)

FLIGHT
ASSAULT LASERS

AGRAV GENERATOR
POWER CONVERTER

DROID STARFIGHTER

Droid Starfighters reconfigure themselves from flying (upper right) to fighting (main drawing) mode and sprout legs for planetary visits (below).

marathon: The Control Ship originally wasn't supposed to be in the film. "The design evolved after the fact," he says. The Trade Federation spacecraft were all going to be a similar shape. "As George [Lucas] was writing the story he realized he wanted a battleship that was completely different. That is why the [Droid] Control Ship evolved."

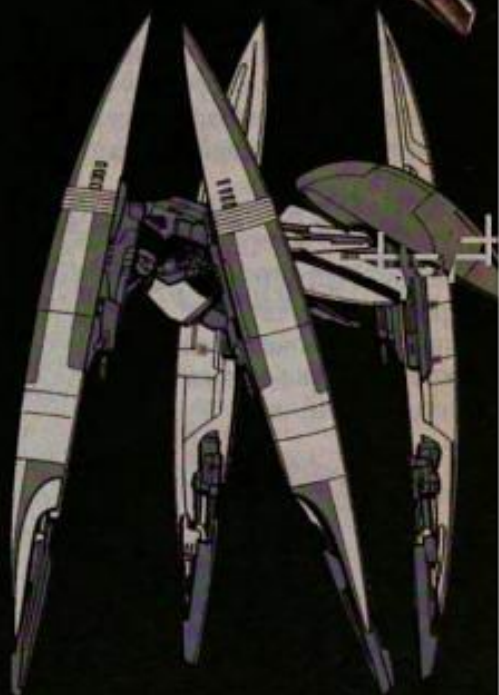
Chiang began the design process by applying a lesson he had learned from working with Lucas. "George likes simple shapes and simple forms," he says. "He really wanted to bring in a saucer-shaped vehicle." And so the Control Ship took

form, not as a derivative of a 1950s-era bicycle-wheel space station—which it closely resembles—but as a giant flying saucer.

Saucers might fly in 1950s science fiction movies, but 1990s fans demand more action. "As we got into it, we found it was very hard to tell direction, so George decided to put engines on it. I started playing around with making it a more exotic shape. George liked that idea. It slowly evolved where it became this doughnut, with the giant claw in the front to give it some personality."

Easy enough for Chiang to say. Now it was up to Reynolds to make it seem realistic enough to convince fans who would sit through the film a dozen times and study his cutaways with a magnifying glass. The first problem was that the location of the various hangars

Chiang (left) developed the concepts for the machines. Reynolds worked under the hood.



in the Control Ship had to flow with the action in the film. "In this case it was very straightforward," says Reynolds. "Doug described how the ship functioned. I wanted to present a cutaway so you could follow the story." Two British illustrators, Hans Jenssen and Richard Chasemore, created the cutaways shown on these pages.

Reynolds needed to fill other spaces aboard the Control Ship





Up close, a fully unfolded battle droid appears more amusing than menacing.

from his own imagination. "I asked [Chiang], 'What are these big bulges for?' And he said, 'They look cool.'" Not a lot of technical direction, but more than enough if you know the story line. The Control Ship, Reynolds explains, is a converted freighter. Reynolds conjectured that to move smaller trading ships safely toward the massive structure the crew would have to use some sort of guidance mechanism, say a tractor beam. And so the bulges that Chiang had added to look "cool" became the housings for an imaginary tractor beam mechanism.

A Yellow Starfighter

The land vehicles in "Episode I" are the end product of the same balancing act that seeks to stretch the viewer's



imagination without straying too far from the bounds of reality. Take the evolution of the Multi-Troop Transport (MTT). The massive craft is used to land droid armies on planet surfaces. Chiang says he selected the bulbous shape of the MTT to evoke the visceral fear inspired by the sight of a charging elephant. The story line called for packing each MTT with enough battle droids to pose a formidable-looking army. The trick was to explain how they could all fit inside. A pencil solved the problem—droid passengers fold up.



POWER
CONVERTER GRIDS

KUAT PREMION MK. II
POWER GENERATORS

RACK EXTENSOR
DRIVE ENGINE

HEAVY-DUTY REPULSOR
COOLING FINES

"The MTT evokes the visceral fear inspired by a charging elephant."

CONTROL ROOM

BATTLE DROID PILOT

For More On Science

Check the Science channel on the PMZone Web site.
<http://popularmechanics.com/popmech/sci/1HOMESCI.html>

Not all of the design decisions reflected a passion to remain faithful to the story line and the laws of

physics. The Naboo Starfighter is yellow, for example, because Lucas wanted a yellow plane. And the Royal Starship looks like a piece of art deco jewelry because a particularly beautiful piece caught Chiang's eye while he was thinking about the ship's design. And so it went with everything you will see in the film: imagination, enhanced with just enough reality to make you a believer.

Although the first screening of

MULTI-TROOP TRANSPORT

The transport that brings battle droids to the front lines is intended to provide a realistic way to cross varied terrain and breach heavily defended fortifications.

MAIN TROOP DEPLOYMENT HATCH

BATTLE DROIDS RACKED IN COMPRESSED FORM

REPULSORLIFT SLED

HEAVY FORWARD ARMOR

TWIN BLASTER CANNONS

"Episode I" is scheduled for well after this issue of PM has gone to press, we suspect the film will be as dazzling a success as the "Star Wars" movies of a generation ago. With a cast that includes the incredible machines we've just seen, we don't need to wish Lucas, Chiang and Reynolds good luck. The Force is with them.

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LIMITED EDITION STAR WARS COLLECTOR POST

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JUNE 1999

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THE PHANTOM MENACE

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George Lucas's Latest
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GLASS BRIDGES

Stronger than steel, these dazzling structures will change the art of bridge building.

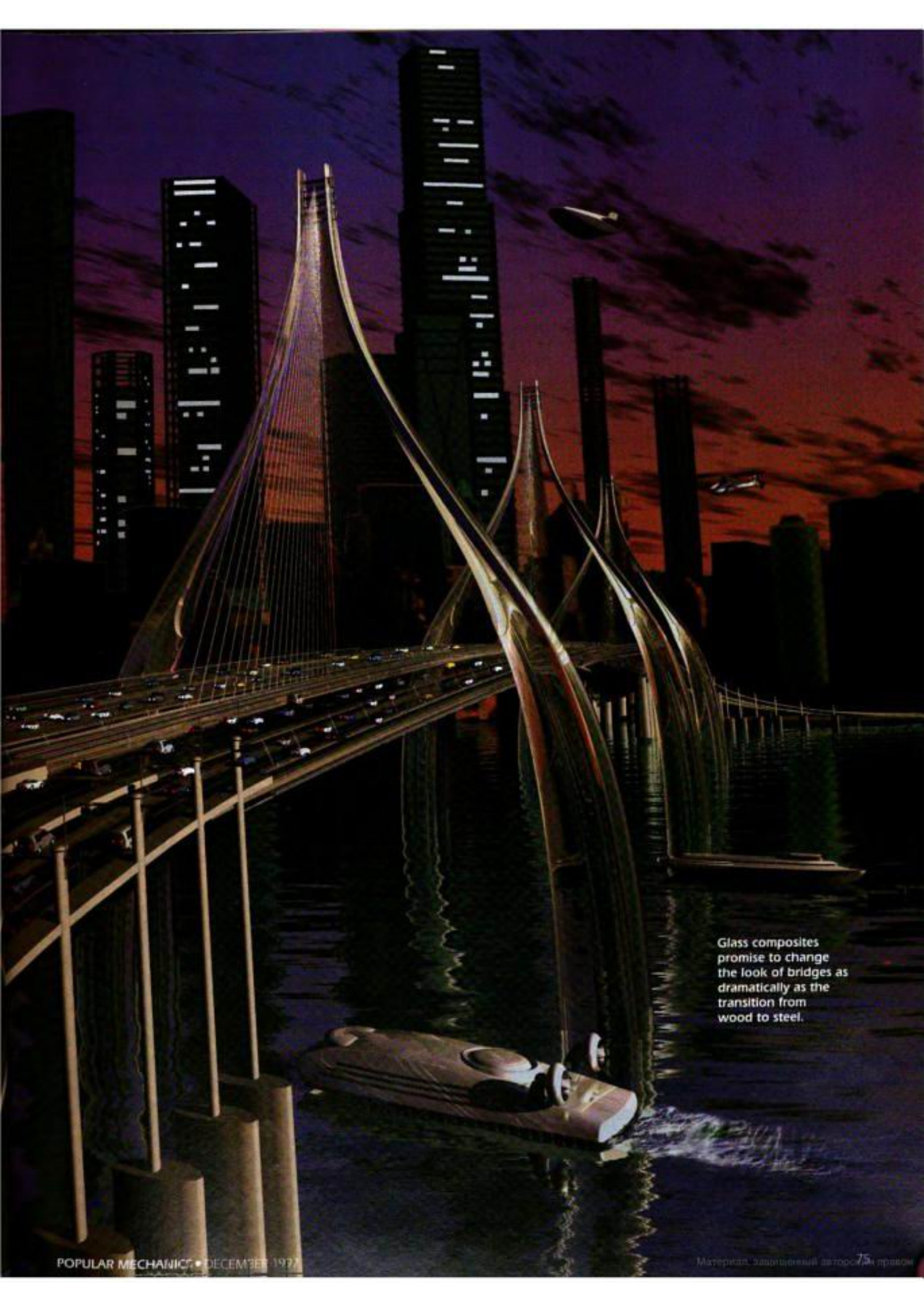
BY JIM WILSON, Science/Technology Editor
PM Illustration by Peter Bollinger

● Steel, the undisputed king of bridge building materials for more than a century, is about to be dethroned. The usurper? A commoner with a regal air: ordinary sand, spun into gossamer threads of glass.

This new leader may have some people who build steel bridges worried about losing their jobs. But they don't have to worry—yet. In years to come, their numbers, like steel bridges, are expected to dwindle mainly through attrition. And the reason boils down to a simple equation of time and money. Traditional steel-and-concrete bridges that cross roads, rivers and gullies are corroding faster than their owners can repair or replace them.

"Civil infrastructure is in





Glass composites
promise to change
the look of bridges as
dramatically as the
transition from
wood to steel.

GLASS BRIDGES

bad shape," says John Scalzi, who directs the National Science Foundation's (NSF) large structural and building system program. Scalzi says 42% of the nation's nearly 600,000 bridges need repair and are obsolete. To do the necessary work, the Federal Highway Administration says it will cost at least \$50 billion.

Even if the money were in hand, which it isn't, some structural engineers question the wisdom of building bridges as we have in the past. Recent surveys of the nation's bridges reveal that traditional steel-and-concrete structures are beset by fundamental design flaws. "Steel rods embedded in concrete for reinforcement and concrete both corrode over time from moisture and salts that seep through cracks," Scalzi says.

Replacing steel with glass fibers might extend the life of a typical bridge from 50 to as long as 200 years, he says. To determine if glass, or perhaps some other material such as plastic or carbon fiber is the best replacement for steel, NSF has funded 40 research efforts.

Among them is the work being done by Frieder Seible, a structural engineer and director of the University of California at San Diego's Charles Lee Powell Structural Research Laboratories. Seible is known around the globe for designing some of the world's most advanced composite structures. He invited **POPULAR MECHANICS** for a look at his work with glass bridges.

After reviewing the basics of composite bridge building in his La Jolla, California, office, we headed to his laboratory. "So, this is where I will finally see a glass bridge?" I asked, stepping

off the curb onto Matthews Lane.

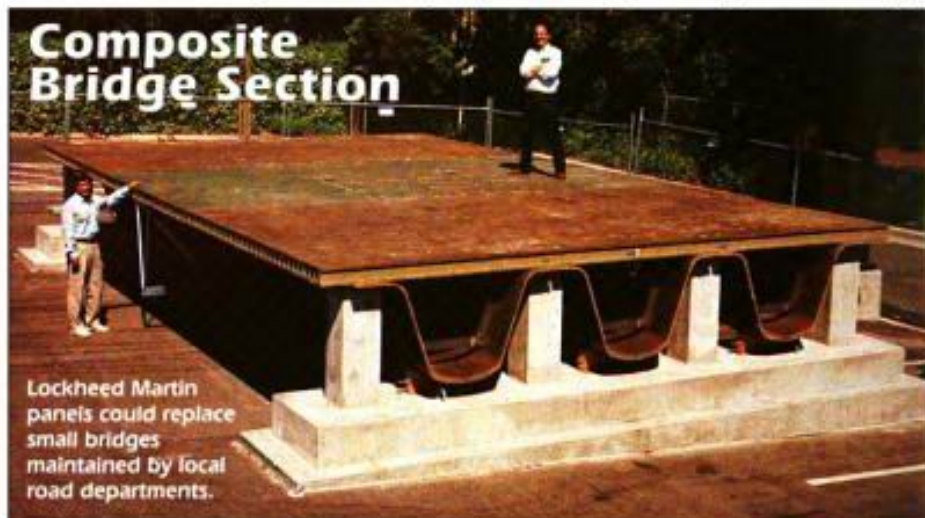
"You're walking on it," he said matter-of-factly.

Sure enough, the section of road beneath my feet looked different from the rest of the street. The asphalt had been replaced by glass bridge decking. It's black and roughly finished, not transparent as I expected. "We weren't trying to make it pretty," said Seible, "just strong."

Seible continued across the street while I performed my own test. I jumped up and down on the panel. It felt like an ordinary road. An ap-

computer workstations record the panels' silent screams as they are "tested to failure." A pile of crushed panels that resembled a collection of broken surfboards was stacked in the parking lot. Running my fingers through some of the translucent yellow glass fibers, I couldn't help but marvel at how these delicate, corn silk-like threads can be so amazingly strong. Threads hanging from the top panel form a hinge that allowed me to lift the end piece. It was surprisingly light.

The weight-saving potential of composite bridge decking also has caught



Composite Bridge Section
Lockheed Martin panels could replace small bridges maintained by local road departments.

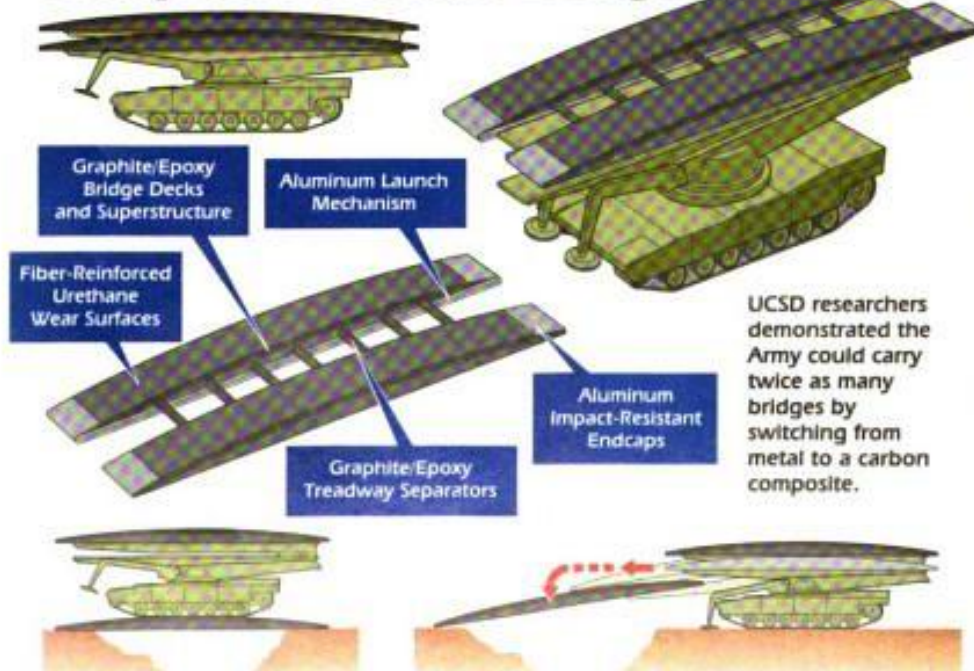
proaching transit-mix truck sent me scurrying to the sidewalk. Braking a few feet from where I was standing, the truck's rear wheels pivoted on the glass panel as it turned into a driveway. "We put the panel here to take advantage of the construction traffic," Seible said.

Inside the laboratory, Seible's team was subjecting other panels to more scientific tests. Strain gauges wired to

the attention of the Army, which has a unique bridging problem. During a ground invasion, armored units must cross ravines or man-made ditches. Currently, the Army uses portable metal bridges that are mechanically "launched" from the top of turretless tanks. The problem is that because the bridges weigh 12,500 pounds, only one can fit on each vehicle. "Making it possible to carry two bridges would double the range of existing launch systems," says John Kosmatka, one of Seible's colleagues. Kosmatka has designed a 13-ft.-wide, 50-ft.-long non-metal assault bridge for the Defense Advanced Research Projects Agency (DARPA). Made of a carbon fabric similar to material used in golf clubs, it weighs only 9000 pounds but can support the weight of a 70-ton tank.

Defense contractor Lockheed Martin (LM) also has its eye on composite bridges—in its case, glass bridges for the civilian market. At LM's Palo Alto, California, research laboratory, scientists have successfully tested a glass bridge that they say will span distances up to 140 ft. According to an LM spokesman, spans this size and smaller account for 70% of the U.S. bridge market. To show that glass could carry the load of heavy traffic, engineers had a 70-ton army personnel carrier drive on top of an 18-ft.-wide by 30-ft.-long section. It is an astounding burden for a 23,000-pound bridge to

Composite Assault Bridge



UCSD researchers demonstrated the Army could carry twice as many bridges by switching from metal to a carbon composite.

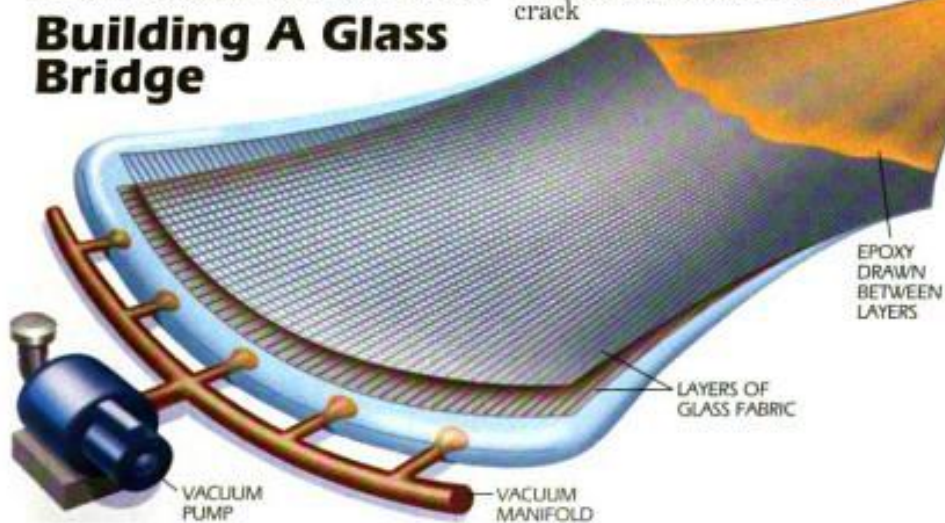
bear. Later, engineers loaded 115,000 pounds on the span. That is a far heavier load than the 80,000 pounds currently allowed on interstate highways.

The most impressive number generated by the LM test is a small one, the \$5-per-pound cost of the bridge's components. It is a critical number for bridge designers. Steel-and-concrete bridges now cost between 30 cents and \$1 a pound, according to LM. But they also are five times heavier than glass and cost more to maintain. This puts the LM glass bridge in the same economic ballpark, countering the steel industry's claim that composite structures are too expensive to be taken seriously. On top of that, the cost of building glass bridges is likely to decrease. "There are aspects of the design and fabrication methods where costs can be reduced," says LM's chief project engineer, Chris Dumlao. "We also expect the cost of raw materials to decrease as market demand for fiber and resin increases."

Even if the cost of building them doesn't fall dramatically, glass bridges still have several important advantages over steel-and-concrete spans. The first is quick assembly, the top priority for county bridge authorities that need to knit together communities isolated after their small bridges have been swept away by storms. It took only five weeks for LM's subcontractors to build the demonstration bridge. Once assembly lines are set up, spans for these areas could be turned out in even less time.

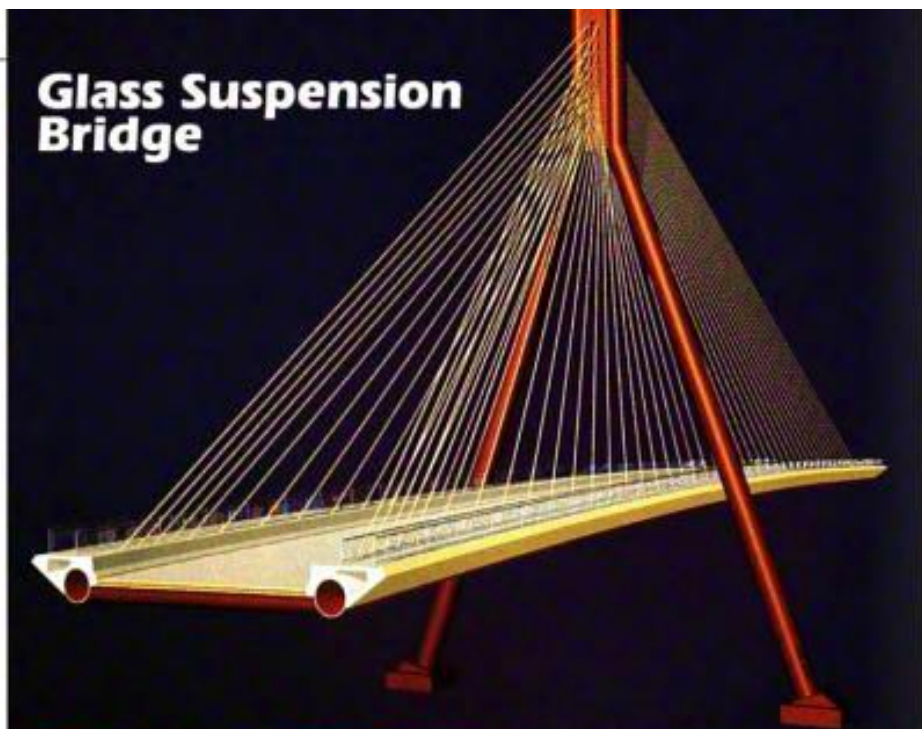
Unlike steel bridges, glass bridges also could be designed to be self-monitoring, perhaps even self-maintaining. One approach being tested by the Naval Research Laboratory uses

Building A Glass Bridge



lengths of specially etched fiberoptic cable. Light shone through the cable undergoes a frequency shift if the cable experiences a change in its thermal or mechanical load. An inexpensive computerized instrument could watch for these changes and alert a

Glass Suspension Bridge



Anticipating more demand, Owens Corning has expanded its glass fiber production (above and right). UCSD design (top) hints at the shape of bridges to come.



repair crew to exactly where the bridge needed to be fixed.

Scalzi says other researchers have suggested placing networks of epoxy-containing tubes among the structural fibers. An impact hard enough to cause a tiny crack

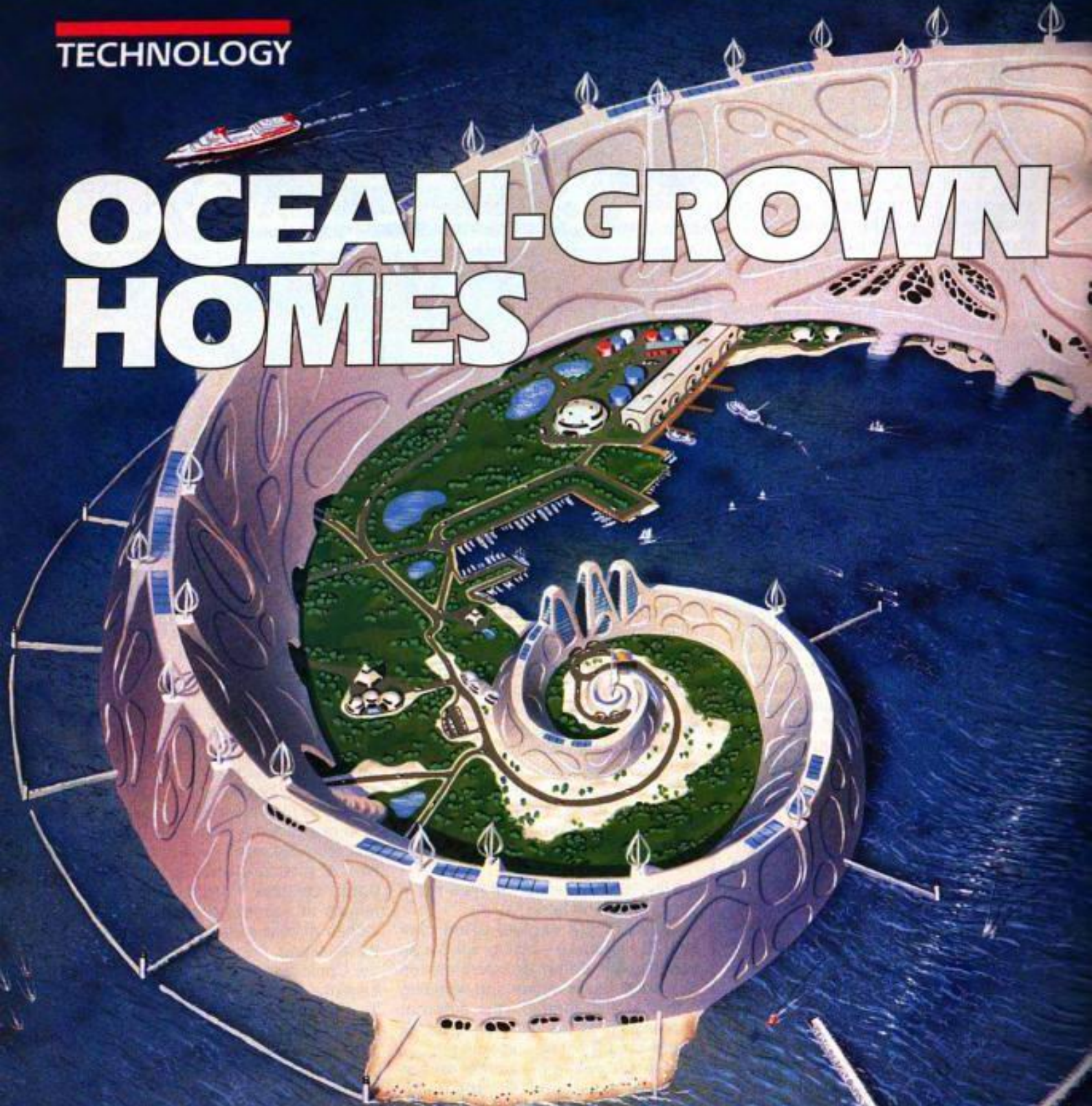
sion of the process Kosmatka used to build his portable bridge for DARPA. To build a large glass bridge, a mat of glass fabric wrapped with plastic would be draped from vertical supports. Once stabilized, a vacuum pump would be connected to one end and it would draw a stream of epoxy from tanker trucks at the opposite side. The epoxy-saturated mat would be allowed to cure for several weeks or months. The plastic cover would then be stripped away, revealing a multicurved design as natural as the tug of gravity.

Proponents of composite bridges acknowledge many technical issues must be addressed. There is some evidence, for example, that the sun's ultraviolet rays might reduce the strength of glass fibers. While painting would solve this problem, it also would tarnish the image of composites as low-maintenance materials, which is, of course, one of the justifications for their higher costs.

No one can predict how this question or other technical issues will be sorted out. What is known for certain is this: The 21st century promises to be the future home of the most ageless of beautiful bridges.

FM

OCEAN-GROWN HOMES



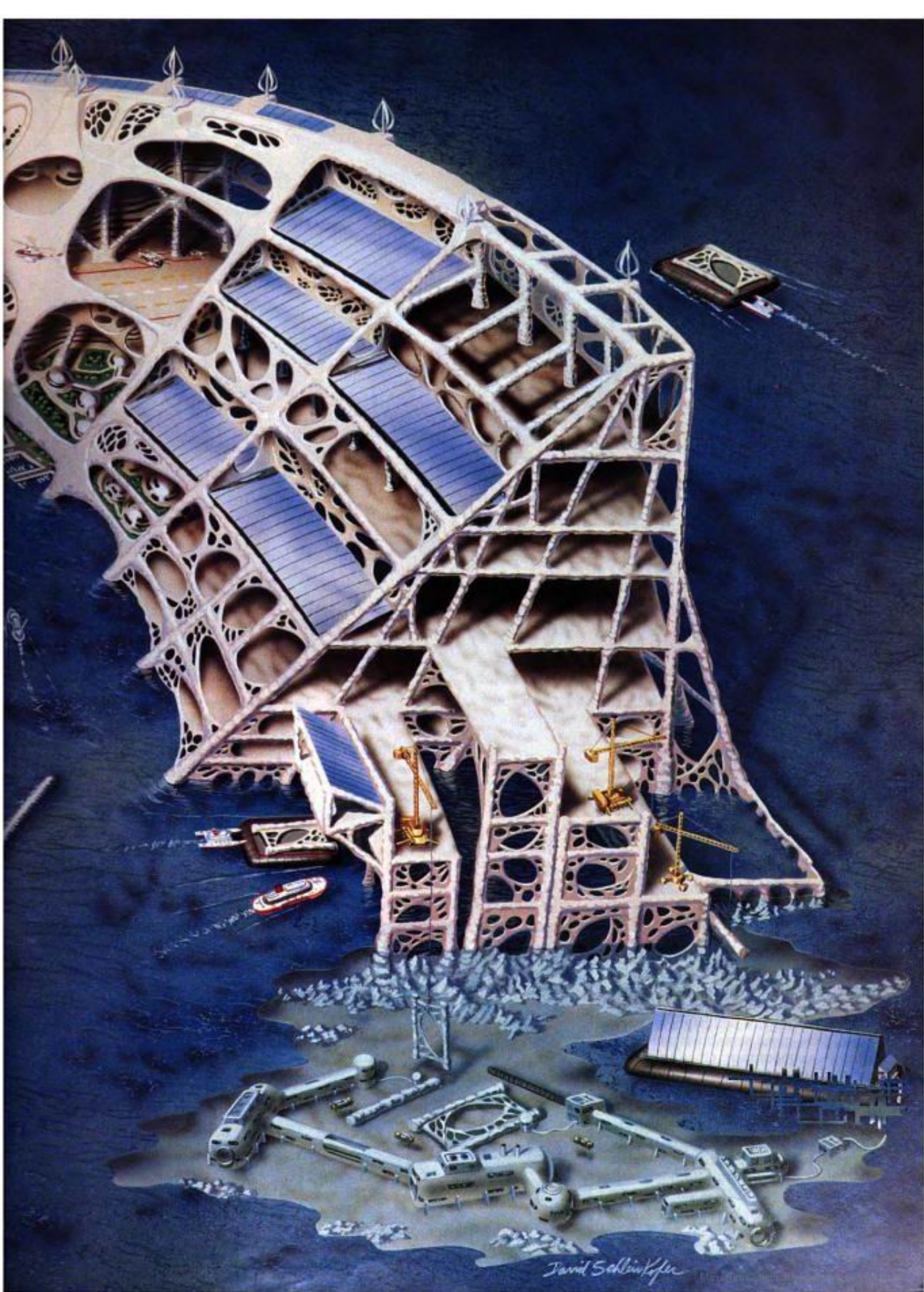
The seas absorb carbon dioxide from the air. Wolf Hilbertz wants to use it to build low-cost housing.

BY ANDY TURNBULL; PM Illustration by David Schleinkofer

● A cargo ship drops anchor in choppy water 300 miles off the coast of North Africa. With practiced efficiency, its crew deploys the ship's crane and begins hauling house-size wire frames and reels of thick electrical cable from the hold. As quickly as this cargo appears topside, it is flung overboard, disappearing into the gray, swirling

sea. When the decks are finally clear, the crew begins assembling floating solar panels that look like adult-size tinkertoys. The ship's engines rumble as the first of these ungainly structures is hoisted skyward and carefully deposited alongside. The activity continues until they form a vast spiral that dips below the horizon as the ship

Once completed, Autopia Ampere would become entirely self-sufficient. Wind and sea currents would provide energy. Marine life, both wild and cultivated, would furnish food. The "mineral accretion" process from which the island was built would be used to create building materials for global export. The underwater manufacturing process itself would help to control the buildup of CO₂, which is a greenhouse gas.





Coral (right) inspired Hilbertz's ocean-derived building process, which forms limestone on wire forms (below).



steams away. Five years later, a luxury cruise liner drops anchor at precisely the same place. Instead of finding bobbing rafts, the passengers lining its decks see the thriving island of Autopia Ampere. With a population of 50,000, it is the newest destination for "eco-tourists," an honor befitting its stature as the first city to rise from the sea.

All of this is the dream of German architect Wolf Hilbertz. It represents the ultimate application of the "mineral accretion" building technology he pioneered when he was an associate professor of architecture at the University of Texas. Simply put, Hilbertz has found a way to use sunlight to turn the minerals in seawater into limestone.

Autopia Ampere will begin as a series of wire-mesh armatures anchored atop a sea mountain. Once in place, they will be connected to a supply of low-voltage direct current produced by solar panels. Over time, electrochemical reactions will draw minerals from the sea to the armatures, creating walls of calcium carbonate, which is what us landlubbers commonly call limestone. (See illustration on page 57.) In much the same way that a household sponge absorbs water, the oceans absorb CO_2 . By removing carbon-containing compounds from the

oceans, the mineral accretion process would help reduce the buildup of CO_2 , which is a greenhouse gas.

The idea works in practice as well as theory. Hilbertz began modestly enough, by growing a coating of limestone on wooden piles wrapped in chicken wire at 30 piers on the coasts of Texas, Louisiana and California. He is now a visiting professor of architecture at the Hochschule fur Kunst in Bremen, Germany, and an adjunct professor at McGill University

in Montreal, Canada, and he has moved on to a larger project. He invited **POPULAR MECHANICS** to see a sample of his handiwork that is using the same technology to build artificial reefs off Jamaica.

Working with the Negril Coral Reef Preservation Society, Hilbertz now has five experimental reefs growing around the island. Three of the experiments use power from the shore. A fourth uses a "sacrificial anode," in effect making a wet-cell battery from



Hilbertz constructs a mineral-collecting wire form.

nearby seawater. The fifth runs on solar power.

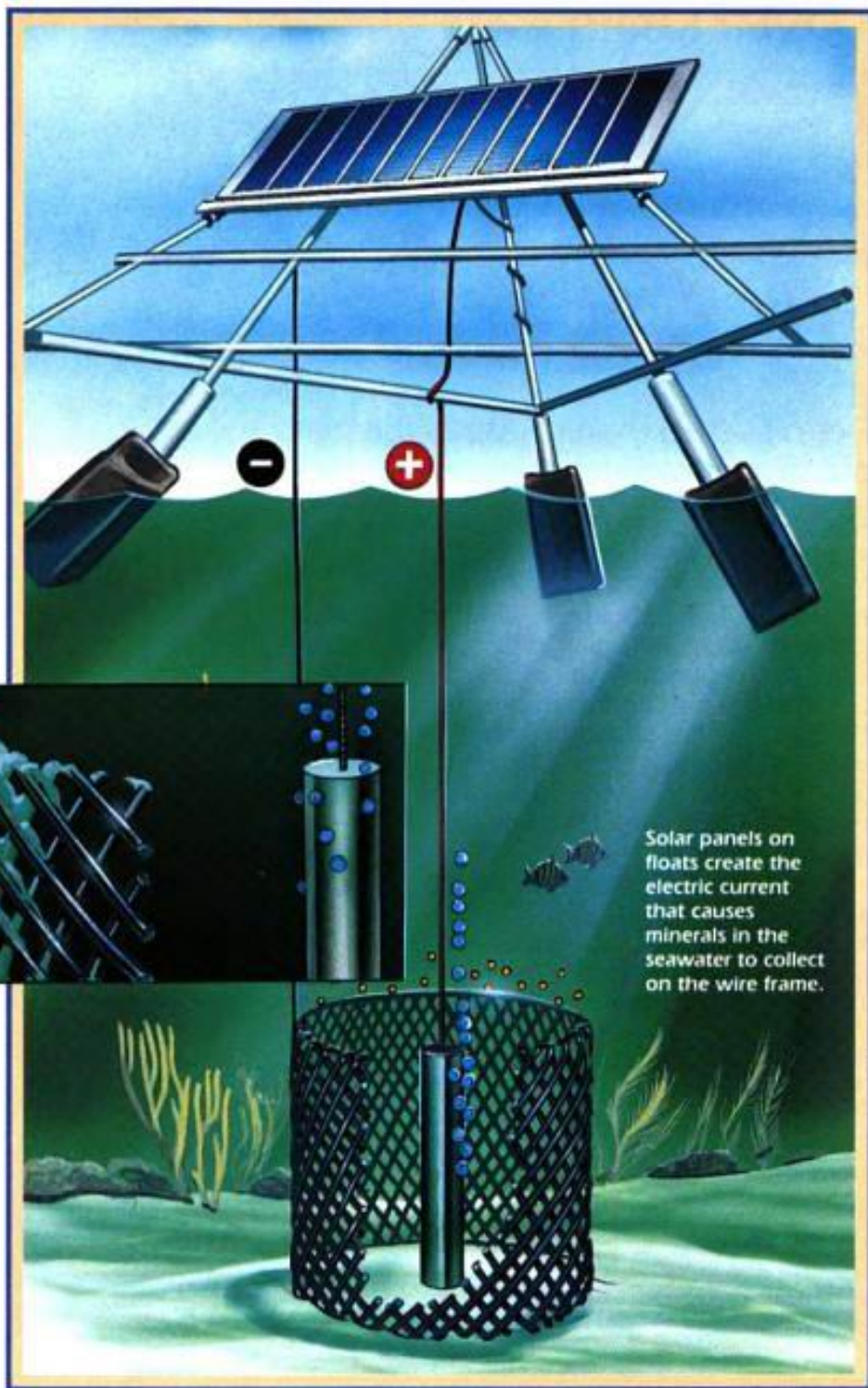
As a step toward his ultimate ocean-grown city, Hilbertz has planned to grow a self-sustaining island city on Seamount Ampere, which is situated about halfway between the Madeira Islands and the tip of Portugal. If constructed, it will extend 50 ft. down to the bottom of the Atlantic in that spot. Besides shallow water, the site offers good fishing, a dependable ocean current, and polymetallic nodules on the ocean floor that contain copper, cobalt, manganese, nickel and iron.

A huge limestone dam will surround the city, Hilbertz says, and building components will be grown in the sea, as shown in the illustration (right). Solar and wind generators will furnish power. So too will a thermal energy conversion system that will extract power from temperature differences among different ocean currents.

One of the cornerstones of the new city's economy would be "limestone farming." The mineral accretion technique that has built reefs in the Caribbean and that could one day build marine cities could also make building components for use on land. Using appropriately shaped wire forms, the minerals deposited from seawater could grow building blocks, wall panels or complete building components just like those that would build a sea-born city, but for use on dry land.

Hilbertz envisions these products being lifted directly out of the sea into barges and ships, which could deliver them to seaports around the world. A limestone farm in the Caribbean could efficiently ship the building materials to coastal areas of North and South America, Europe and Africa, to inland North American ports on the St. Lawrence Seaway and Mississippi River systems, to most of Central Europe via the Rhine, Rhone and Danube rivers and to most of the Amazon basin in Brazil. A farm in the South Pacific could service the west coast of North and South America, and booming Pacific Rim countries.

Hilbertz also envisions others of his cities becoming centers for an under-sea mining industry. The seafloor is believed to be littered with metal- and mineral-rich nodules, from which refiners in a city will produce pure metals. The fact that metals refining is an energy-intensive activity isn't the least bit daunting. He enthusiastically describes a plan in which the sea would "grow" limestone conduits that would tap deep, slow-moving ocean currents and guide them through the blades of giant hydroelectric plants.



Whatever Hilbertz's cities manufactured, their occupants would dine on the bounty of the sea. Wild fish would be guided into nets, and domestic fish would be raised in pens, along with cultured abalone, sea urchins, oysters, mussels and other shellfish. Useful seaweeds will be cultured, and more common vegetables would be grown in hydroponic chambers.

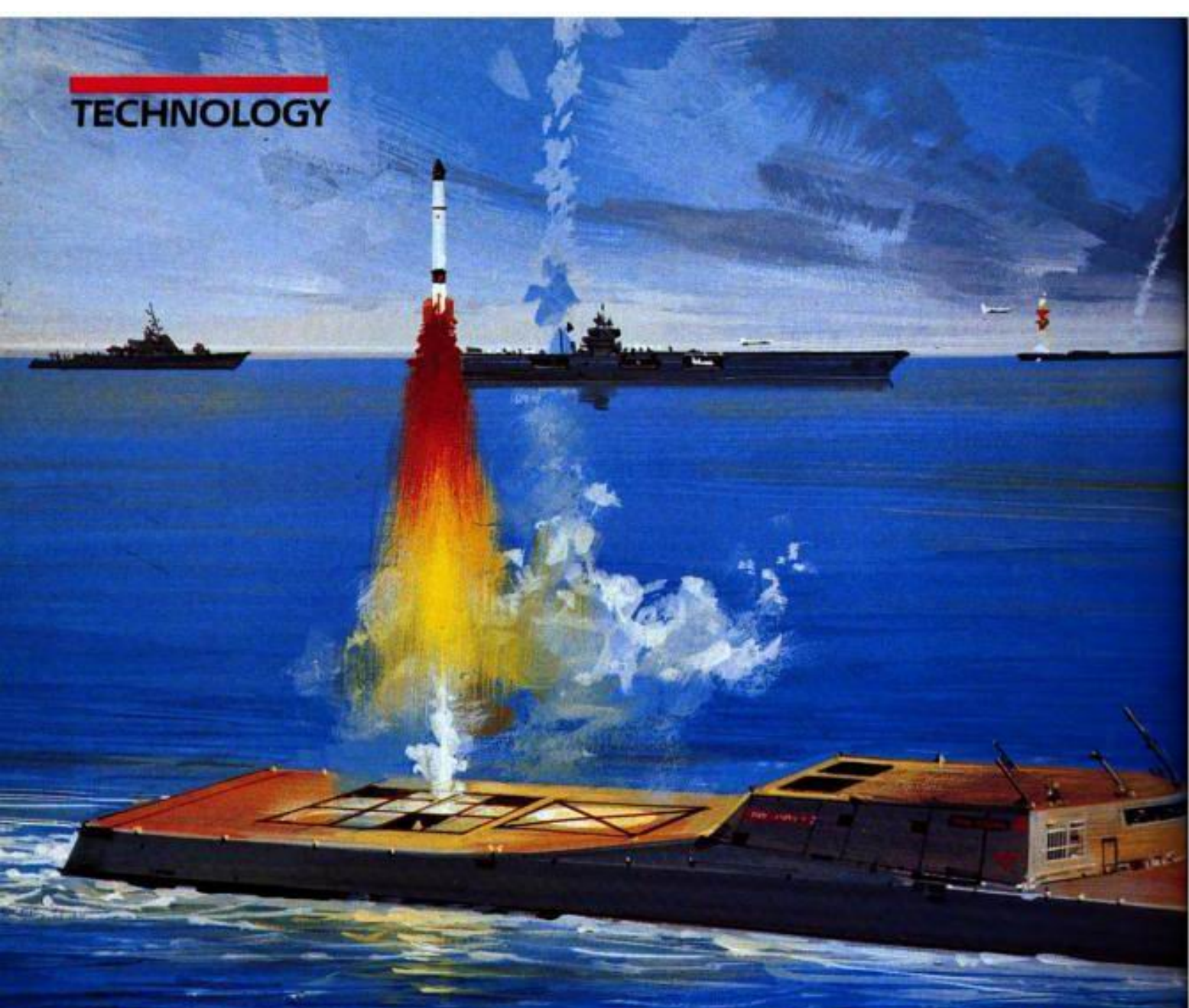
The fact that ocean-grown cities could stand on their own economically and become independent and self-governing entities poses what Hilbertz believes to be one of the biggest barriers to their creation. He says there is no legal precedent regarding national ownership of a newly formed island that is beyond a

nation's territorial waters.

He plans to face this issue head-on with an experiment on Skerki Bank, in the Mediterranean Sea. The bank consists of a few-hundred square yards of knee-deep water between Tunisia and Sicily. It's in international waters, but within the area both Italy and Tunisia claim as an "Exclusive Economic Zone."

Hilbertz hopes to start growing an island there before the end of the year. "We'll establish our presence there and stake a claim, and see what happens. If anyone challenges us, we have lawyers ready to argue our case. We've had so many legal opinions that we decided just to go ahead and see what happens," he says.

FM



ARSENAL SHIP

The Navy's planned class of stealthy attack ships delivers nothing but firepower.

BY SCOTT GOURLEY; PM Illustration by John Berkey

● It's the middle of the first decade of the 21st century, and a modernized Iraqi Army is conducting yet another round of maneuvers near the border of Kuwait. The U.S. responds to the hostile troop buildup cautiously, since elements of the Army's 82nd Airborne Division and the U.S. Marine Corps are already in Kuwait, participating in a multinational exercise. Suddenly, unlike past maneuvers that stopped short of the border, the Iraqi spearhead accelerates its advance, aiming to quickly seize significant oil assets in Kuwait.

Without warning, the spearhead enters the jaws of hell.

"He gets bloodied on day one," says Rear Adm. Alexander Krekich, director of surface warfare for the U.S. Navy. Krekich recently talked to *POPULAR MECHANICS* about the Navy's emerging concept for a

devastating new weapon it calls the Arsenal Ship. In Krekich's fictional scenario, the ship faced a hostile force that had attacked with little warning.

"With something like an Arsenal Ship on station—and for first-cut purposes, let's say [it's carrying] about 500 missiles—you could very easily do significant damage early on to stop a hostile force in its tracks. By doing that, you allow your forces to respond. You are able to counterattack earlier, which helps to reduce your casualties. The Arsenal Ship denies the enemy the advantage of surprise in the early stages of the conflict."

The Navy's Arsenal Ship concept has been in development for the past year and a half through a series of studies led by Adm. J.M. Boorda, chief of naval operations. The discussions focused on the need for a new class of



Five hundred missiles, no waiting: The Arsenal Ship could support troops ashore with devastating firepower.

could deliver overwhelming firepower ashore during the early stages of a conflict.

Although the Navy has not released any drawings of the ship, descriptions paint a picture of a relatively low-cost vessel operated by a small crew. And while the Navy declines to cite specific cost projections, early estimates have reportedly ranged from \$500 to \$800 million for the ship itself. Crew size estimates run in the neighborhood of 20 to 100 personnel.

The vessel would carry as many as 500 missiles in a vertical launch configuration, and it would have a high degree of survivability, perhaps featuring a double hull or limited stealth characteristics. Its maintenance requirements would be low and it would be able to remain on station for extended periods, with crews rotating for 6-month tours of duty.

The Arsenal Ship is significantly different from the Metcalf Strike Cruiser concepts of the mid- to late 1980s. Referring to PM's July 1988 cover story, "America's New Fighting Ships," Krekich explains that the earlier concept showed a huge ship loaded with sensors and related combat systems. The design reflected the existence of both the Soviet Union and the Cold War. The new concept drops the sophisticated combat systems in favor of a simpler ship carrying a larger number of missiles.

The greater reliance on missiles reflects the maturation of missile technologies over the past 10 years. In addition, the Navy's Aegis Weapons System provides the Arsenal Ship with a complementary structure to perform the necessary combat-systems work. By linking through the sensors and combat systems of an

ARSENAL SHIP

accompanying Aegis cruiser, the Arsenal Ship could fire its sophisticated weapons at hostile forces with tremendous accuracy.

Arsenal Ship planners are currently addressing these linkage and accuracy challenges. "What we're looking for is a new way to do the links for the command and control architecture, the C4I [command, control, communications, computers and intelligence], if you will, and how all the data will come in," says Krekich. "The concept has gotten to this point: If you're going to support the forces ashore, the forces ashore will tell you where the missiles and gunfire should go. A latitude and longitude for each [target] is



The Vertical Launch System Mk 41 (above and below) can launch a wide variety of missiles. A Tomahawk is fired at right.

fine. We'll put a round there and put it there the first time. Hopefully, we can do that through a lot of links and not through a lot of manual input, as we did in Vietnam."

Boorda emphasizes that the Arsenal Ship is not designed for a specific weapon. The vessel will be able to fire any Defense Department weapon that



can be launched vertically. Candidates include the Standard missile, the Evolved Sea Sparrow missile (ESSM), varieties of the Tomahawk cruise missile, theater ballistic missile defense weapons, the Army Tactical Missile System (ATACMS) and even an advanced version of the Multiple Launch Rocket System (MLRS).

The Standard Missile-2 (SM-2), for example, is the Navy's primary surface-to-air fleet-defense weapon. Most recently, the Navy has been developing the SM-2 Block IV, which will operate in conjunction with the Aegis Weapons System and Vertical Launch System Mk 41 to provide improved all-weather fleet-area defense against both aircraft and cruise missiles. The ESSM reflects a kinematic upgrade to the AIM/RIM-7 Sea Sparrow air-to-air and surface-to-air missile. The upgrade also will provide increased lethality against high-speed antiship cruise missiles at greater intercept ranges.

The all-weather Tomahawk long-range subsonic cruise missile can be launched against targets on land or sea. The Tomahawk Land Attack Missile (TLAM/C) and the Tomahawk Antiship Missile (TASM) carry unitary conventional warheads, while the TLAM/D variant carries submunitions.

The existence of traditional Army systems such as ATACMS and MLRS in the Arsenal Ship's proposed weapons inventory reflects the Navy's intention of providing fire support to forces ashore. In the case of ATACMS, the Navy has already conducted at-sea firing tests (see *Tech Update*, page 32, Dec. '94). The Army used ATACMS Block I missiles in Operation Desert Storm and is likely to rely on the devastating missile in future conflicts.

According to Boorda, the mix of weapons on the Arsenal Ship would depend on the specific mission. For example, the vessel would carry plenty of ATACMS if the scenario called for significant artillery support. A rack of Tomahawks would be loaded if the vessel was to conduct first-day strikes in support of manned bombers. A situation with heavy anti-aircraft warfare operations or the threat of scud missiles would mandate a different missile mix.

"We've got to see what is reasonable and what we can accommodate," says Krekich. "But we are looking essentially to make a difference in the initial days of a conflict by providing heavy firepower. And, quite honestly, do significant damage to an enemy early on and not allow him to have any advantage whatsoever."

The first Arsenal Ship could enter the fleet by 2001 or 2002.

PM



The Arsenal's Arsenal



Candidate missiles for the Arsenal Ship: THAAD knocks out tactical ballistic missiles. Tomahawk attacks targets on land or sea. ATACMS provides fire support to ground forces. Standard gives surface-to-air defense. ESSM targets antiship missiles.

HIGH SPIES

For 35 years, top-secret reconnaissance satellites have provided America with a keyhole view of a troubled world.

BY PHILIP CHIEN

• In March 1994, a remarkable display went up inside the Central Intelligence Agency's headquarters, in Langley, Virginia, where only cleared personnel could view it. The exhibit: a still-classified Corona spacecraft, one of the original reconnaissance satellites of the 1960s. At the display's dedication ceremony, then-Director of Central Intelligence Richard Helms remarked that he hoped the satellite would one day

sit in the Smithsonian Institution, where Americans could recognize the role Corona played in shaping history.

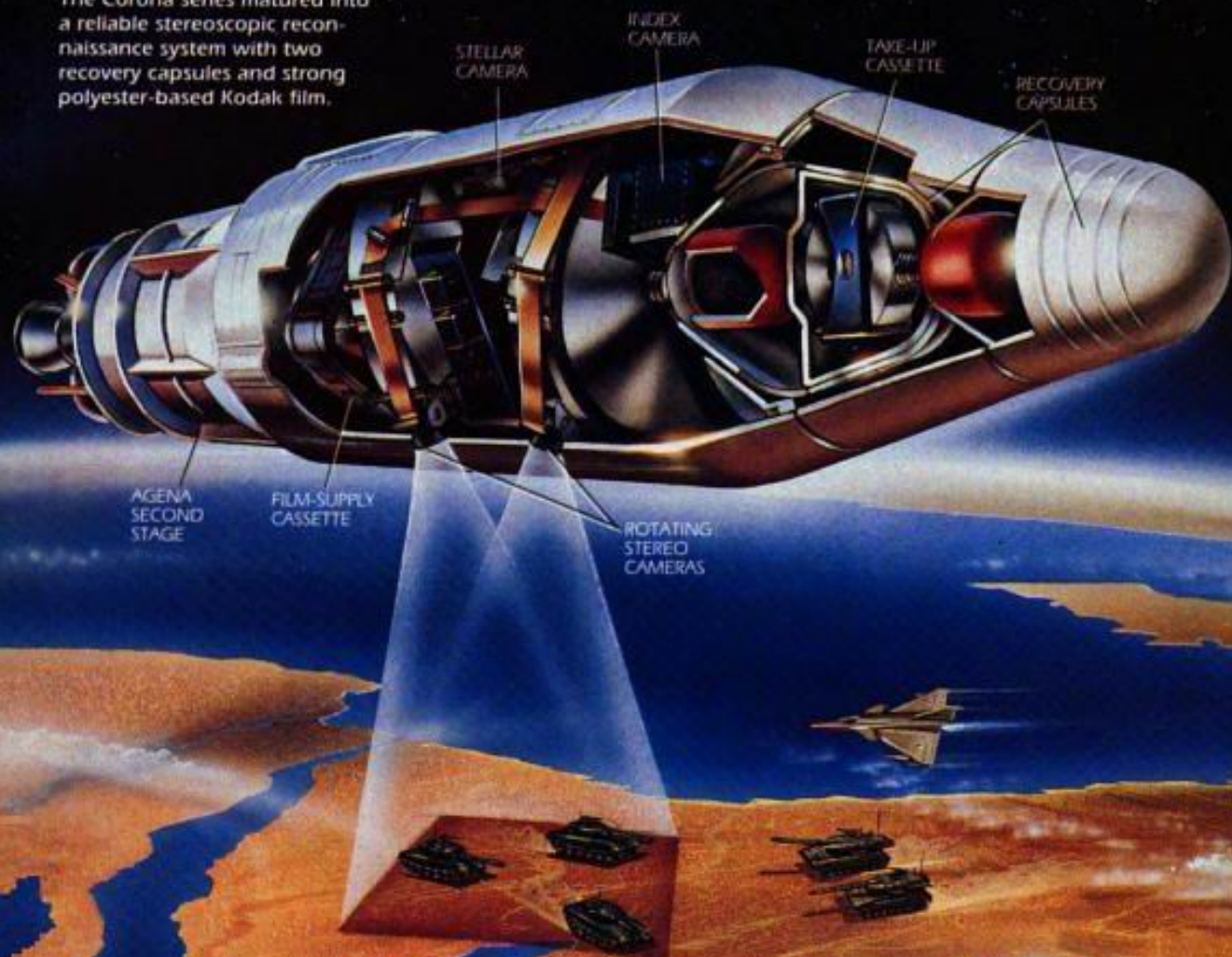
That day is coming—and probably much sooner than Helms thought. Today, the Air and Space Museum is preparing a permanent display of a KH-4B stereo camera and the re-entry capsule used on the very last Corona mission in 1972. On May 24, 1995, the intelligence community posthumously—and quite publicly—honored program manager Richard Bissell and Brig. Gen. Osmund Ritland, who died knowing they were pioneers and heroes but unable to tell their families just why.

All this was set into motion a year ago, when President Clinton issued Executive Order 12951, declassifying images from the Corona program and from two related subprograms. Now, just as Corona



KH-4B

The Corona series matured into a reliable stereoscopic reconnaissance system with two recovery capsules and strong polyester-based Kodak film.



once shed light on our Cold War foes, the declassification is illuminating the clandestine technology that gave us a leg up on those adversaries. Aerospace experts once strained to fathom the hidden workings of the program—just as they puzzle over today's reconnaissance satellites, which remain highly classified.

The Soviet Union's test firing of its first long-range ballistic missile in 1957 is what got Corona off the ground. Although the top-secret CIA/Lockheed U-2 enjoyed success, the spyplane was always one surface-to-air missile away from causing an international incident (which, of course, it did in 1960). So President Eisenhower authorized the CIA to develop photographic-reconnaissance satellites that could soar over "denied territory" with impunity. The Soviets could hardly complain. After all, they had already set a precedent of unrestricted satellite travel four

months earlier with Sputnik 1.

Built by Lockheed Missiles and Space, the Corona vehicles operated under the cover name Discoverer. Their purported objectives were scientific—lofting and recovering mice or other biological payloads to learn how spaceflight affected them. But the early Corona satellites turned out to be lessons in futility. The spacecraft, which were launched on Thor-Agena rockets, were supposed to orbit and then eject recoverable reentry capsules containing the exposed film. But Discoverer 1 never reached space—it crashed near the South Pole. Discoverer 2 flew a near-perfect mission, only to dump its reentry capsule in Norway near the Russian border. Discoverer 3 actually did carry mice, but they wound up in the Pacific Ocean.

Because there was no guarantee that Corona's recovery system would function, work took place simulta-



KH-11 FOLLOW-ON

Modern photoreconnaissance satellite features a high-resolution digital camera, on-board fuel supplies and a data-relay antenna to downlink imagery.

neously on another system, called Samos. With Samos, the film would be developed aboard the spacecraft, the photos scanned and the data radioed back to Earth. But Samos proved a bust and was dropped after only five test flights.

Early failures didn't faze the Corona team. "In those days we were pioneering everything," recalls Forrest McCartney, a flight controller in the program and now vice president for Atlas and Titan launch operations at Lockheed Martin. "When you couldn't recover the reentry vehicle it was a disappointment, and when you would get tumbling 'birds' it was a thrill a minute. It was pretty exciting—and a lot of fun." Ground controllers originally operated from an industrial park on Page Mill Road in Palo Alto, California. Later, they moved to the Air Force Station in Sunnyvale.

Number 13 turned out to be lucky for Corona. Launched August 10,

1960, its capsule carried not cameras but an American flag—the first man-made object to be recovered from orbit. The vehicle orbited 17 times. A communications foul-up prevented an Air Force C-119 aircraft from snaring the reentry capsule in midair. Instead, Navy divers had to fish it out of the ocean.

The next mission returned pictures—3000 ft. of film, covering 1.65 million square miles of the Soviet Union. The first useful image: a grainy shot of a Soviet bomber base just 400 miles west of Nome, Alaska. Resolution was crude: the camera could only discern objects 25 ft. across. Corona personnel destroyed the historic spacecraft, overreacting to secrecy instructions from President Eisenhower.

Cold War comfort

By the time the Discoverer series concluded in 1962, the Corona program

had evolved from a problem-plagued effort into a reliable intelligence asset. Corona continued as a classified project for another decade, however. In all, 145 satellites flew into space. Over the course of those 10 years, the resolution of Corona's camera sharpened to 6 ft., stereo cameras were introduced and a second "bucket," or reentry capsule, was added to permit longer missions with more film.

During its reign, Corona's achievements proved pivotal to American foreign policy. A steady return of overhead images kept the Pentagon on top of Soviet missile-site activity. Corona revealed the truth behind the "Missile Gap"—the headline issue in the 1960 presidential campaign. There was indeed a missile gap, but the United States had the upper hand. Furthermore, in 1964, a Corona photograph gave national-security officials a 2-month warning that China was about to join the nuclear club. In 1967, satel-

Popular Mechanics

FEBRUARY 1996

INSTALL A
BEAUTIFUL
HARDWOOD
FLOOR

CLASSIFIED

NOW WE SPY ON THE WORLD

For 35 Years, Our Super-Secret
Satellites Have Given Us The
Intelligence Edge

WILDEST VIDEO GAME YET

You Control The
Action With Your
Mind

**NOW!
PAGERS
THAT TALK**
Will They
Replace Your
Cell Phone?

**MOST FUN
YOU CAN
HAVE ON
WATER**

'96 Jet Boats
Pack Big Power,
Small Price



Trucks really are a drag. Engineers want to get rid of that drag, and they're turning to wind-tunnel testing to do it.

The reason is obvious: Less drag means more fuel economy. With the pump price of diesel fuel having doubled between 1973 and 1974, a 100,000-mile-a-year hauler can save \$1300 on even a modest 10 percent fuel-cost reduction.

Today's trucks

Many of today's trucks already have a number of gimmicks that make them more fuel-efficient: roof-mounted air dams, vortex stabilizers, faired tanks, gap seals between cab and trailer, thermatic fans, radial tires, higher axle ratios and lighter materials.

Tomorrow's trucks will go even farther into streamlining—*true* aerodynamic streamlining—to help save fuel. The boxy shapes of today will have to give way to some laid-back profiles and a lot rounder corners.

But with extremely high tooling costs for radical new designs, you

might not see the big streamliners on the highway right away. Sweeping changes always take time.

Current state of the art

Meanwhile, what's the state of the art at the moment? We already know a lot more than we can do anything about.

For example, NASA began playing around with truck shapes in 1974 and found that a 40-inch gap between a normal tractor and trailer gives 10 percent better fuel mileage than does the normal 62-to-64-inch spacing.

NASA researchers went on to test the various drag foils now on the market. They discovered that the most common roof-mounted air dam cuts drag up to 24 percent at 55 mph in still air.

A gap seal between truck cab and trailer, NASA found, reduced drag up to 19 percent.

Translated into fuel savings, the figure for both the air dam and the gap seal came to about 10 percent.

NASA then went on to another set of

experiments involving not trucks but vans. They added aluminum exterior skins to a test van—first to make it a perfect box with 90° corners. They called this Configuration A. Then NASA commenced to round off the corners and seal the underbody. Proceeding down the alphabet, Configuration E proved the best streamlined, with a three-quarter-length bellypan and all corners rounded. Drag reduction of E came to 61 percent.

This isn't to say that all drag foilers work. Nor that those that work in still air do much good when there's a side wind. Experiments have shown that some types of truck roof spoilers actually *create* drag, and that others which do some good in still air lose their efficiency when they're bucking a moderate to heavy crosswind.

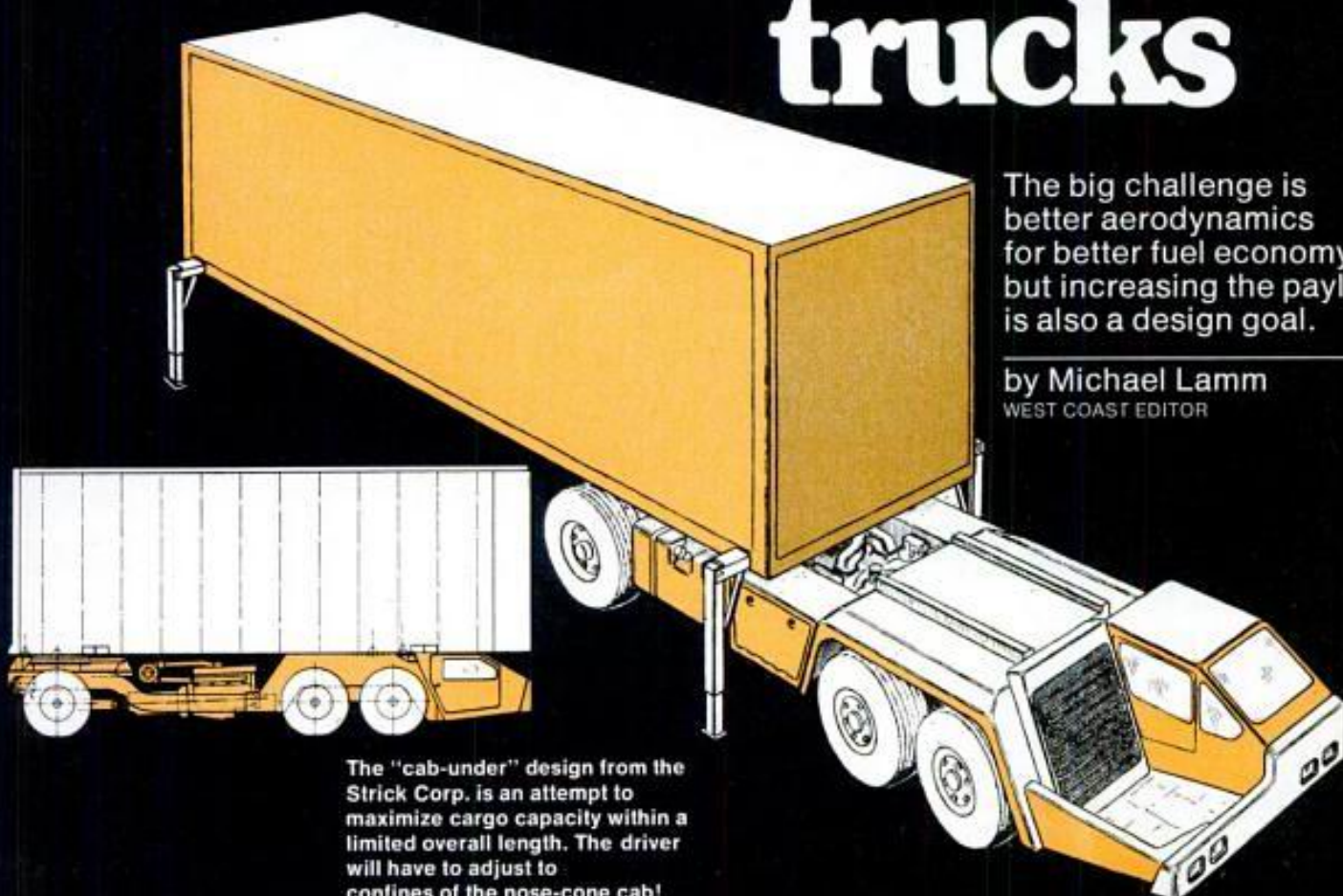
Testing on the road

One of the most ambitious and impressive recent truck streamlining experiments involves Ryder Systems, Inc., the Miami-based leasing/trucking firm. In 1974, Ryder built 10 highly

PM Previews Tomorrow's trucks

The big challenge is better aerodynamics for better fuel economy, but increasing the payload is also a design goal.

by Michael Lamm
WEST COAST EDITOR



The "cab-under" design from the Strick Corp. is an attempt to maximize cargo capacity within a limited overall length. The driver will have to adjust to confines of the nose-cone cab!

Tomorrow's trucks

streamlined COE (cab-over-engine) tractors. Ryder's idea was to test truck aerodynamics—to try to see in actual on-the-road practice how streamlining affects long-haul fuel economy.

Nine of Ryder's slope-nosed prototypes were put into service—three by Ryder and six in other companies. The tractors themselves were totally new, not just re-bodied versions of production tractors. They used stock Cummins diesel engines so fuel economy could be checked against conventional rigs with identical powerplants.

Oregon trucker Dean Hobbensiefen, working with one-eighth scale models, evolved the shape of these Ryder COEs. Ryder engineer Harleigh Holmes and University of Maryland researchers refined the original shape by placing scale-model trucks into the university's wind tunnel. In arriving at the final shape, they tried various fairings, spoilers, skirts, V'd trailer noses, seals between tractor and trailer and so forth.

In recent 290-mile-loop test runs in Indiana (240 miles on interstates and 50 miles on city streets), the Ryder protos posted 33.5 percent better gas mileage than equivalent "normal" trucks. The conventional trucks averaged 5.0 mpg; the streamlined Ryder rigs got 6.7 mpg. In terms of money, that's a saving of \$4100 a year based on 100,000 miles of driving and 50 cents a gallon for diesel fuel.

Nose-cone tractor

Another very interesting concept has been developed by Strick, Inc., the trailer manufacturer in Fort Washington, Pa. Strick engineers have

attempted to maximize the carrying capacity of the largest legal tractor/trailer combinations by reducing the size of the tractor and thus upping the volume of the trailer.

They've tucked a small, streamlined, one-man tractor under the leading edge of a lengthened and lowered trailer. The driver, surrounded by glass in this small "nose cone," sits at about the same height as he would in a conventional car.

The Strick design puts the trailer pivot atop the cab roof, and the concept was originally proposed with four-wheel steering, high-flotation single tires and up to 80,000-pound GVW. The Strick truck puts primary emphasis on cargo capacity and only secondary stress on streamlining. Spokesman Ron Zubko says that Strick is now going into its second generation of the same basic idea.

What does all this activity mean? When and how will the truck revolution come?

Economic incentive

It's hard to give an exact timetable, but during the Ford administration, there was talk suggesting that truckers "voluntarily" boost fuel economy by 18 to 25 percent. There's nothing the industry would rather do. Whether President Carter's energy policy will speed up fuel-economy measures remains to be seen.

You can bet, though, that either way whether brought about by government recommendations or not—the trucks that you see coming down the road in the future will be more streamlined. It's inevitable. ★ ★ ★

SOME IDEAS YOU'LL SEE ON TRUCKS OF THE FUTURE

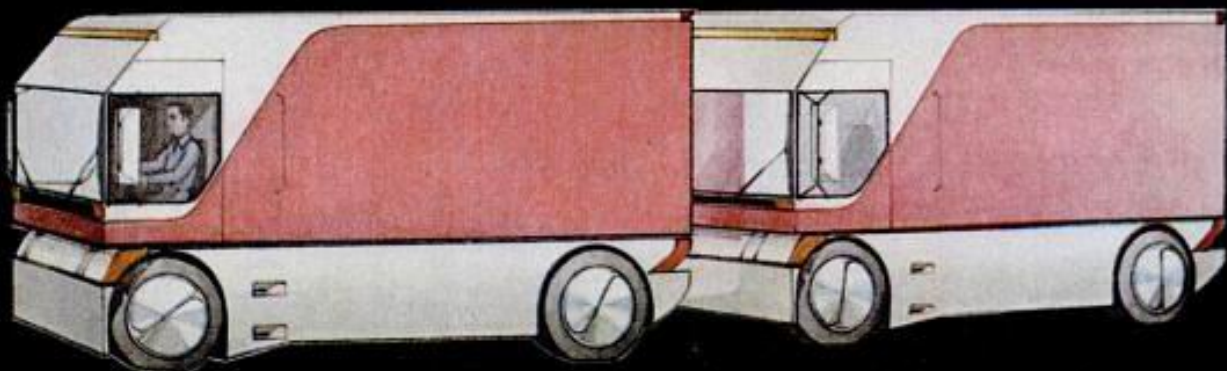
LONG, SLOPING WINDSHIELD OF ULTRATHIN TEMPERED GLASS GIVES GOOD VISIBILITY AND RACE-CAR AERODYNAMICS.



CAB TAPERS OR NARROWS TOWARD FRONT TO CUT THROUGH THE AIR MORE EFFICIENTLY. THIS REQUIRES THE FRONT AXLE TO BE MOVED AFT.

SEPARATE, SELF-POWERED TRUCKS ARE COUPLED TOGETHER WITH ONE DRIVER IN THE FRONT UNIT.

INDIVIDUAL UNITS ARE USED DURING THE DAY FOR CITY PICKUP AND DELIVERY. AT NIGHT, TWO OR MORE UNITS ARE DISPATCHED OVER THE ROAD WITH ONE DRIVER.



FLEXIBLE, LIGHTWEIGHT POLYPROPYLENE
ACCORDION ELEMENT BETWEEN
ALL UNITS CAN IMPROVE
AERODYNAMICS 25 PERCENT.

FULL-LENGTH LOWER
BODY SKIRTS ELIMINATE
TURBULENCE UNDER
TRAILER. EACH SKIRT CAN
BE QUICKLY REMOVED FOR
WHEEL, TIRE AND BRAKE
SERVICE.

CONVENTIONAL CAB:

ENGINE-CAB POSITION IS
REVERSED FOR IMPROVED
VISIBILITY BY ELIMINATING
LONG HOOD. GOOD FOR WESTERN
STATES WHERE BRIDGE LAWS
REQUIRE A LONG WHEELBASE.



CAB HAS ONLY TWO AXLES, BOTH
DRIVEN. ELIMINATION OF
SEPARATE STEERING AXLE REDUCES
WEIGHT, TIRE FRICTION ON ROAD.
TANDEM STEERING SYSTEM HAS BEEN
USED IN EUROPE FOR MANY YEARS.

LCF (LOW-CAB-FORWARD):

GOOD FOR CHASSIS-
CAB CITY TRUCKS
AND MULTISTOP TRUCKS.



BACK-OF-CAB AREA HAS
CLEAN SURFACES FOR IMPROVED
AERODYNAMICS. TRAILER
FITS SNUGLY AGAINST THESE
SURFACES BY MEANS OF
ACCORDION-PLEATED DIAPHRAGM.

COE (CAB-OVER-ENGINE):

GOOD FOR EASTERN
STATES AND CITIES
WHERE A SHORT
WHEELBASE IS REQUIRED.

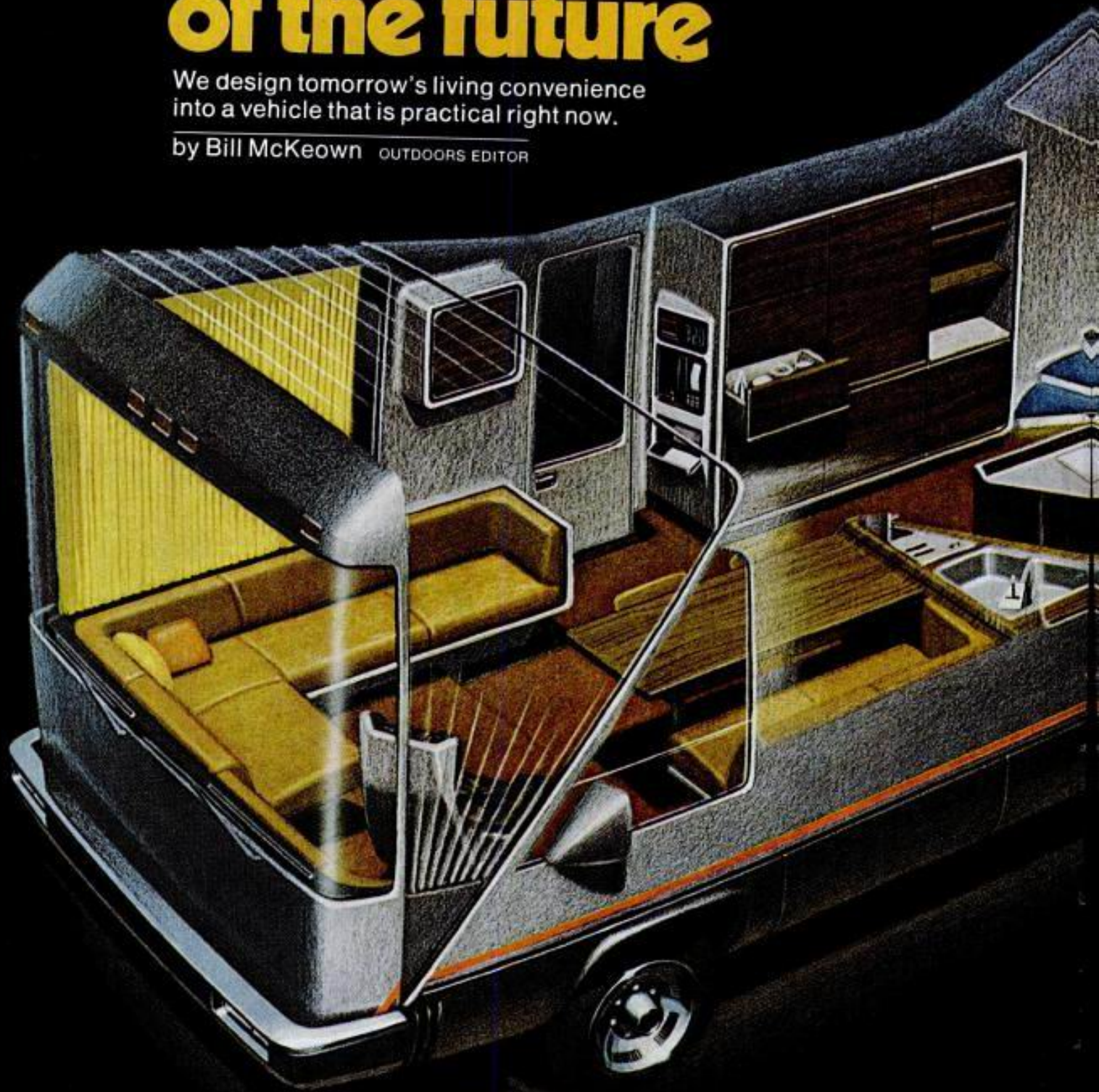


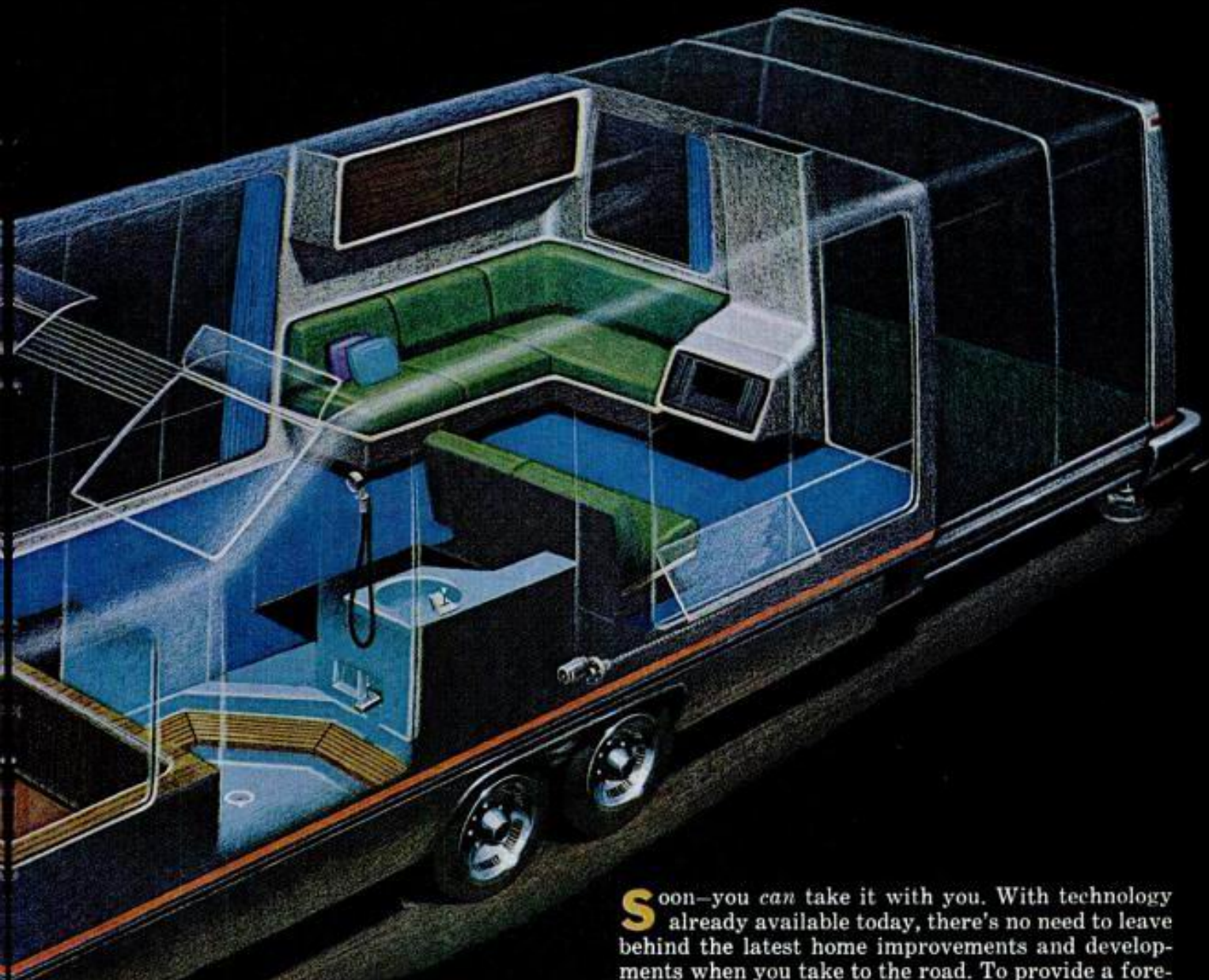
WHEN WHEELS ARE
EXPOSED, DEEPLY
RECESSED CENTERS
ARE COVERED WITH
FLUSH DISCS TO REDUCE
TURBULENCE.

PM's motor home of the future

We design tomorrow's living convenience into a vehicle that is practical right now.

by Bill McKeown OUTDOORS EDITOR





Soon—you can take it with you. With technology already available today, there's no need to leave behind the latest home improvements and developments when you take to the road. To provide a forecast of things to come, *Popular Mechanics* worked with some of the top transportation designers to fit these predictions into a practical package on wheels.

More than the comforts of many a home are presented here in PM's prototype vehicle. It incorporates ideas by industrial designer Ed Westcott and Richard Lee Kessler of Westcott Associates, Westport, Conn., and illustrator Dale Gustafson. Westcott was formerly a designer for Ford and Chrysler, and helped create the Metroliner and airport people-movers. Gustafson spent years in Detroit working on automotive designs for General Motors. The clean aerodynamic lines and light strong materials of aircraft construction used here won't cut the cost of our RV, but will add to safety, durability and fuel economy. Complementing the sleek exterior, and equally important, is the roomy interior arrangement with maximum use of all available space, plus creation of some to spare.

Pull into a campsite of the future and you first expand the front lounge by pivoting forward the streamlined nose. This provides full headroom and, with the front in vertical position, the driving con-



Gone with the wind-resisting frontal area is the shoebox look. Clean aerodynamic lines and strong, light construction aid appearance and fuel economy when front pivots back for driving.

trols and instrument panel can be swung down out of sight, driver's seat reversed and slid forward, and the padded dash hinged down to form a couch that can later become a bed. Instead of individual dials on the dash, digital readouts can give information selected by pushbuttons. A few years from now, speed signs along the road may emit rays that activate a vehicle sensor to display speed limits ahead on a dash panel.

Though PM's travel home is planned for continuous touring and does not have the tilt-out room extenders that are already available in some large park-model travel trailers which stay at one campground for months at a time, it can stretch out quickly in back as well as forward. The split-level layout with raised lounge and bedroom aft makes possible the storage of a patio floor underneath. Actuate the screw-drive mechanism shown and the back of the RV extends to accordion-out a 6-foot back porch. Lower the supporting legs, set up deck chairs, open the back of the lounge fireplace, and get ready for a barbecue as the sun goes down.

Because a traveler often follows the sun to regions of balmy weather, the travel home's roof has a number of flush-mounted solar energy panels to generate power for charging batteries, running communications equipment and heating water as an occasional option in place of generated or plug-in power. Sunlight also floods in through skylights over the sauna and the steps to the upper level, as well as in the large picture windows on both sides of the vehicle. The raised rear section allows storage of airconditioners and the heating unit, a clean roof line results and, without top-mounted conditioners, clearance height is less than that of many motor homes today.

While water and fuel tanks under the raised flooring allow an increased range of action and camping away from hookups, minimum space is required for gray water and sewage holding tanks since the incinerator systems now being introduced are fully utilized.

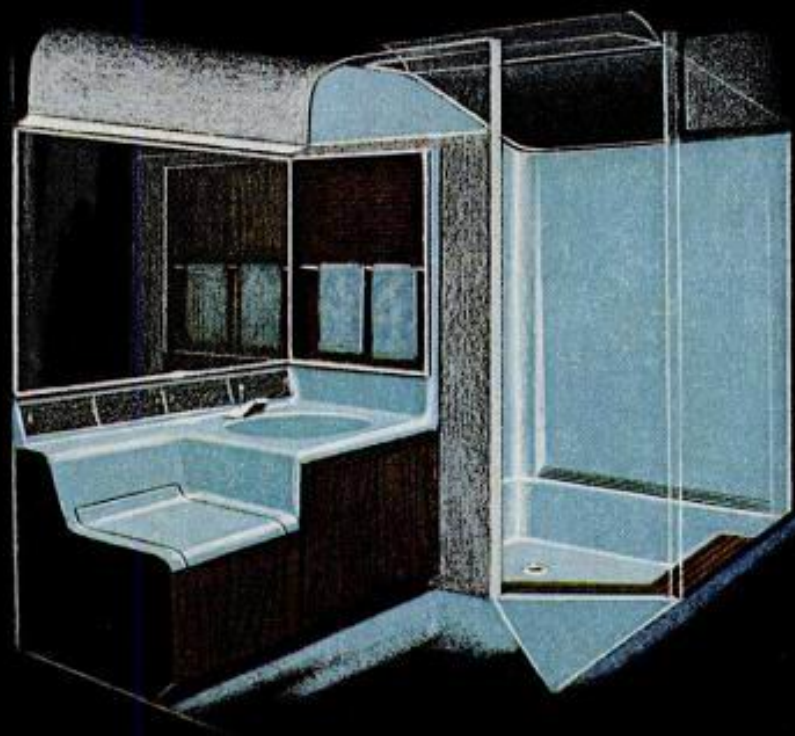
Center of action for entertaining, our kitchen is offered with a bar-height island stove and counter, U-shaped arrangement option or wall-counter with built-in standard and microwave ovens. The shallow spill-proof drawers of the refrigerator wall and tambour-enclosed shelves are handy space-savers.

Builders of large motor homes like Apollo, Landau, Executive, Barth and Bluebird are already offering microwave ovens, bars with built-in TV and other niceties. Here we go beyond to what the future can hold for travel homes away from home. ★ ★ ★

PM's motor home of the future



Command console for driver seats him behind a picture-window windshield and facing a control panel where digital readouts display miles an hour, distance remaining to campsite, miles per gallon, time and distance run, estimated time of arrival, engine temperatures and pressures on demand, gas tank levels and programmed route numbers. Pushbuttons adjust climate control, lights. Control handles can replace steering wheel.



Bathing in luxury can be a pleasing way to start and end a day of driving or camping. Single or dual-privacy compartmented bath has an adjoining sunken sauna with skylight. Split-level arrangement with raised area bedroom-lounge in the aft section of the vehicle allows generous hot and cold water supplies, and holding tanks under the rear flooring.

When you are parked for the night at a pleasant campsite, the motor home front accords out into a vertical position, driver's controls and instrument readout panel pivot down out of the way, front cushioned dash unfolds down into a couch that can later pull out to become a bed. Panel above driver's seat gives rear-viewing TV monitor picture of vehicles behind while motor home is on highway.



Rainy day and evening entertainment is easy in forward lounge-bedroom with TV or cassette movies projected from overhead closed-circuit center. For driving in fog and rain, infrared sensor might be used, aimed ahead and behind, to indicate heat-type images of other vehicles.



Central command and control center can show time, levels in all tanks, inside and outside temperatures, wind data, tape-trip monitor with projected strip map programmed to show present location. Radio and stereo include AM/FM and CB plus a TV antenna direction control, fire and intrusion alarms.



Kitchen arrangements, installed next to the dinette, can use bar or island counter stove (below) or wall counter (above) for cooking convenience en route or in camp. Both regular and microwave ovens are provided; food-preparation appliances are built in; drawer-type refrigerator and freezer pull-out shelves make selection of supplies easy and keep them secure in transit.



CRUISERS (IMPROVED MAXIM GORKI CLASS)
KAGANOVICH KALININ KIROV

DISPLACEMENT
8550 - 9000 TONS
LENGTH, 627 FT.
SPEED, 30 KNOTS
(APPROX.)

P.K.-TYPE SUBMARINE
LENGTH, 320 FT.
10 21-IN. T-TUBES
2 4-IN. GUNS
2 45-MM. AA GUNS
SURFACE SPEED, 18 KNOTS
SUBMERGED SPEED, 10 KNOTS

9.7-IN. TRIPLE
GUN TURRETS

9.7-IN.
TRIPLE GUN
TURRET

IT IS BELIEVED
THIS DOME HOUSES
LAUNCHING GEAR FOR
GUIDED MISSILES
OR ROCKETS

TRIPLE 16-IN. GUNS

CREW

WORKING CHAMBER

MAGAZINES

WATER LINE

CREW

2500-TON DESTROYERS
SPEED (APPROX.) 37 KNOTS
LENGTH
(APPROX.)
400 FT.

FORWARD MAIN
FIRE CONTROL
TOWER

5-IN. TWIN DUAL-PURPOSE GUNS

5-IN. TWIN DUAL-PURPOSE GUNS

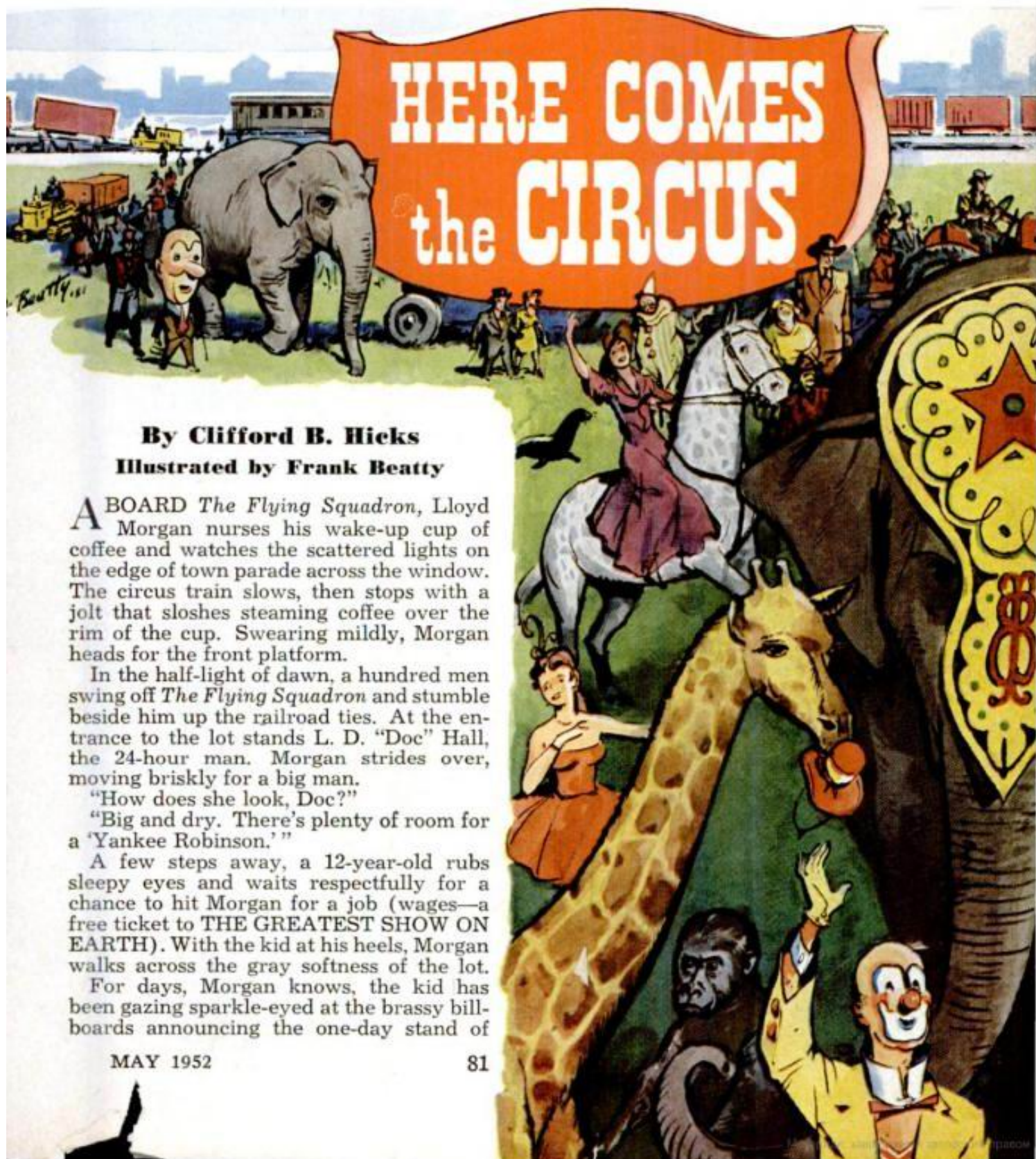
AA GUNS

OIL FUEL TANKS

RUSSIAN NAVY

RUSSIAN and former Polish and German shipyards are working at top speed to build up Soviet sea power. Battleships, cruisers, destroyers and submarines are under construction. Certain details of the new Russian ships are known and depicted here by the British artist, G. H. Davis. The disposition of the main armament of the ships and the guided-missile launching gear (on battleships) has been

Three trains haul the "Greatest Show on Earth"—72,000 tons of it—to three million spectators each year



By Clifford B. Hicks

Illustrated by Frank Beatty

BOARD *The Flying Squadron*, Lloyd Morgan nurses his wake-up cup of coffee and watches the scattered lights on the edge of town parade across the window. The circus train slows, then stops with a jolt that sloshes steaming coffee over the rim of the cup. Swearing mildly, Morgan heads for the front platform.

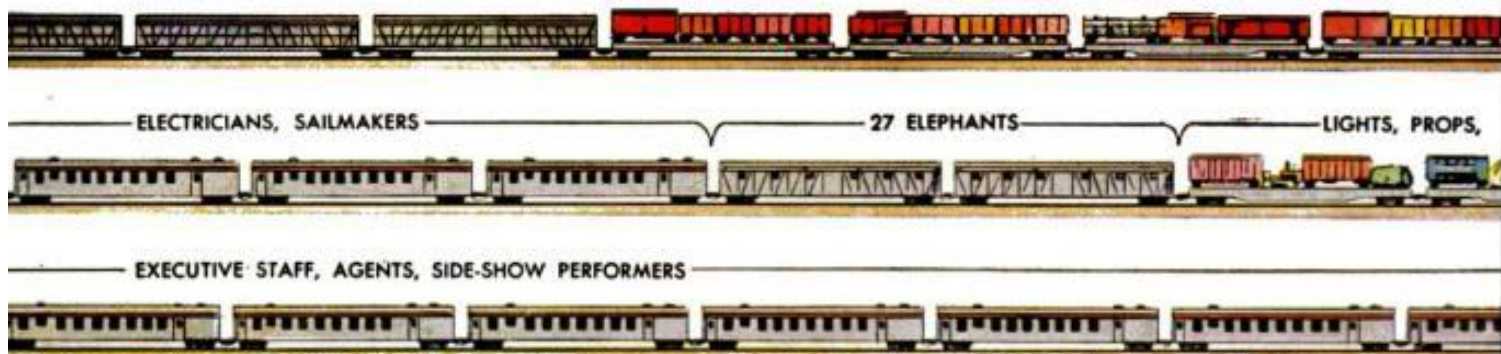
In the half-light of dawn, a hundred men swing off *The Flying Squadron* and stumble beside him up the railroad ties. At the entrance to the lot stands L. D. "Doc" Hall, the 24-hour man. Morgan strides over, moving briskly for a big man.

"How does she look, Doc?"

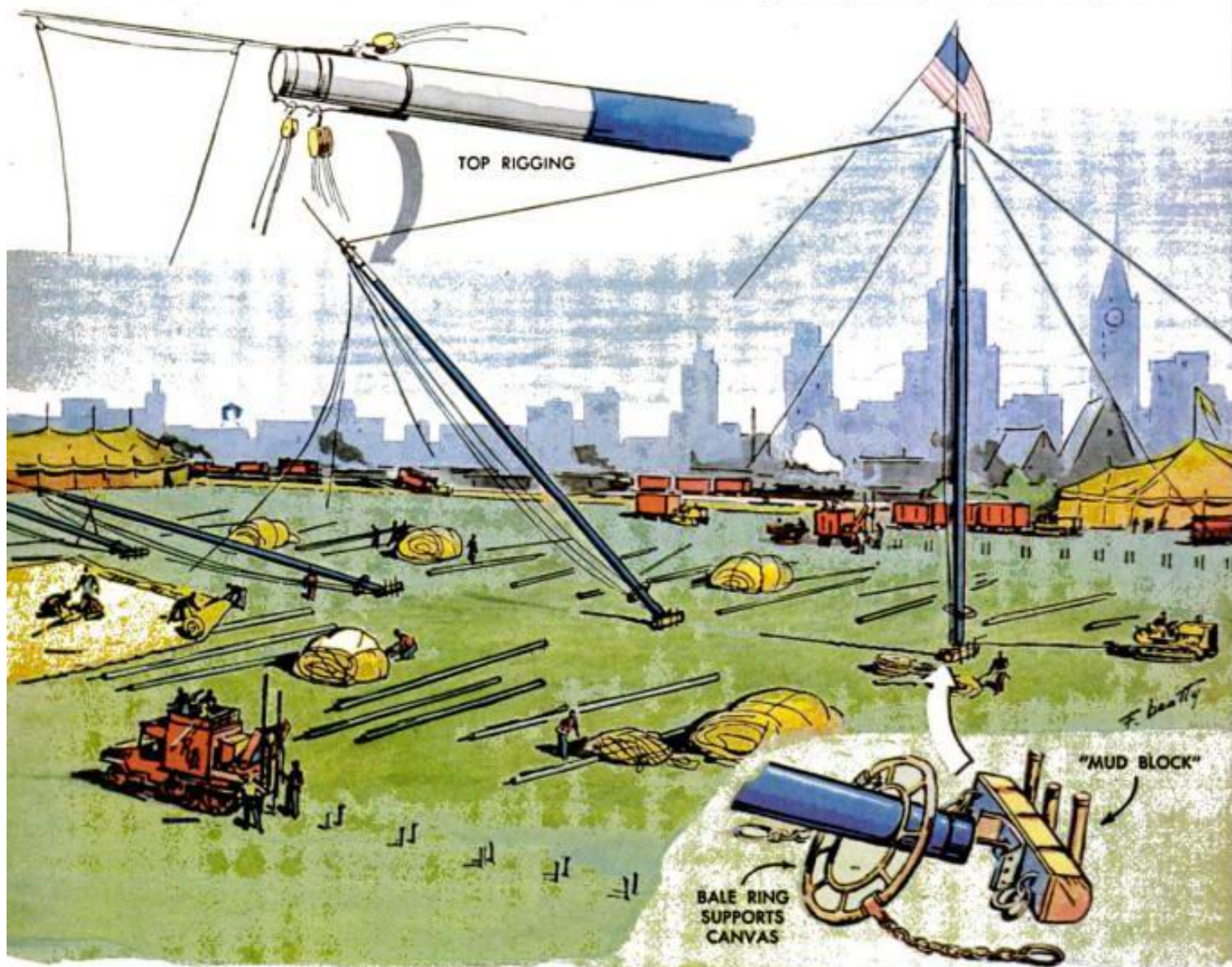
"Big and dry. There's plenty of room for a 'Yankee Robinson.'"

A few steps away, a 12-year-old rubs sleepy eyes and waits respectfully for a chance to hit Morgan for a job (wages—a free ticket to THE GREATEST SHOW ON EARTH). With the kid at his heels, Morgan walks across the gray softness of the lot.

For days, Morgan knows, the kid has been gazing sparkle-eyed at the brassy billboards announcing the one-day stand of



Below, Number One pole, already towering 62 feet above the lot, acts as a skyhook to raise the other poles. Pivoting on a half-round timber against a "mud block," the second pole sways slowly and regally into position



Ringling Bros. and Barnum & Bailey Circus. Actually, there's a misstatement in the printed ballyhoo: The Greatest Show On Earth isn't the prodigious production under the big top, as advertised, but the spectacular sight of a vast canvas city going up at dawn, then melting away for another year barely 18 hours later.

It's Morgan's job as lot superintendent, to see that the world's biggest circus appears, pauses, then vanishes as smoothly as

a rabbit in the hands of the side-show magician. Even to Morgan it's a feat of legerdemain. Packed inside *The Flying Squadron* (first section of the circus train) and its two gaudy running mates are some 72,000 tons of circus, from ponderous pachyderms to gawking giraffes and the rarest of animals from every clime. There are people aboard, too — 1400 of them — from the Fat Lady with her 540 (count them) pounds to the star aerialist and lowliest

AND FLOATS FOR "SUPERSPECTACLES"

COOKHOUSE TENT, KITCHEN, DISHWASHER, REFRIGERATOR, FLOATS,



BIG TOP GEAR

SEAT WAGONS — COVERED WITH COLLAPSIBLE SEATS



SEAT WAGONS — CIRCUS CAN SEAT 8000 PEOPLE



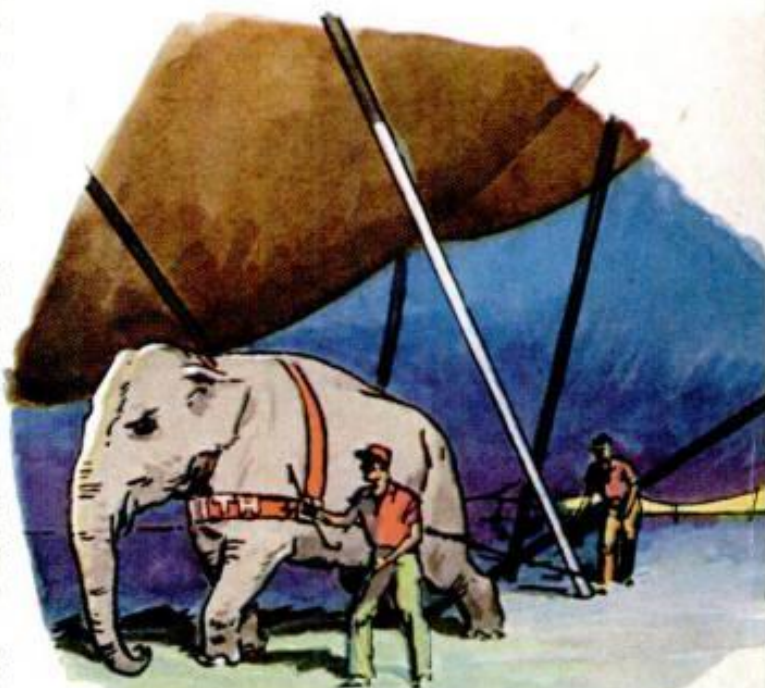
canvasman. Through split-second timing, under the direction of Morgan and the other boss-men, they are able to erect their vast patchwork city for about 430 performances before three million spellbound spectators each year.

And here's the whole spectacle, capsuled into this one-day stand in the sleepy-eyed kid's home town, a miracle of movement, the show behind the show, a sight well worth an alarm clock at dawn.

Pretending he doesn't see the kid, Morgan sets briskly about the business of staking out the circus with flag-tipped metal poles. There's a full 18 acres of room on the lot so he plots a Yankee Robinson, a straightaway layout with the midway, side show and big top visible to the customers, all the rest of the circus staked out in the privacy of the "back yard." On the vast grassy field, under the excited eyes of the 12-year-old, he pegs down the location of every single item now crammed aboard the circus trains.

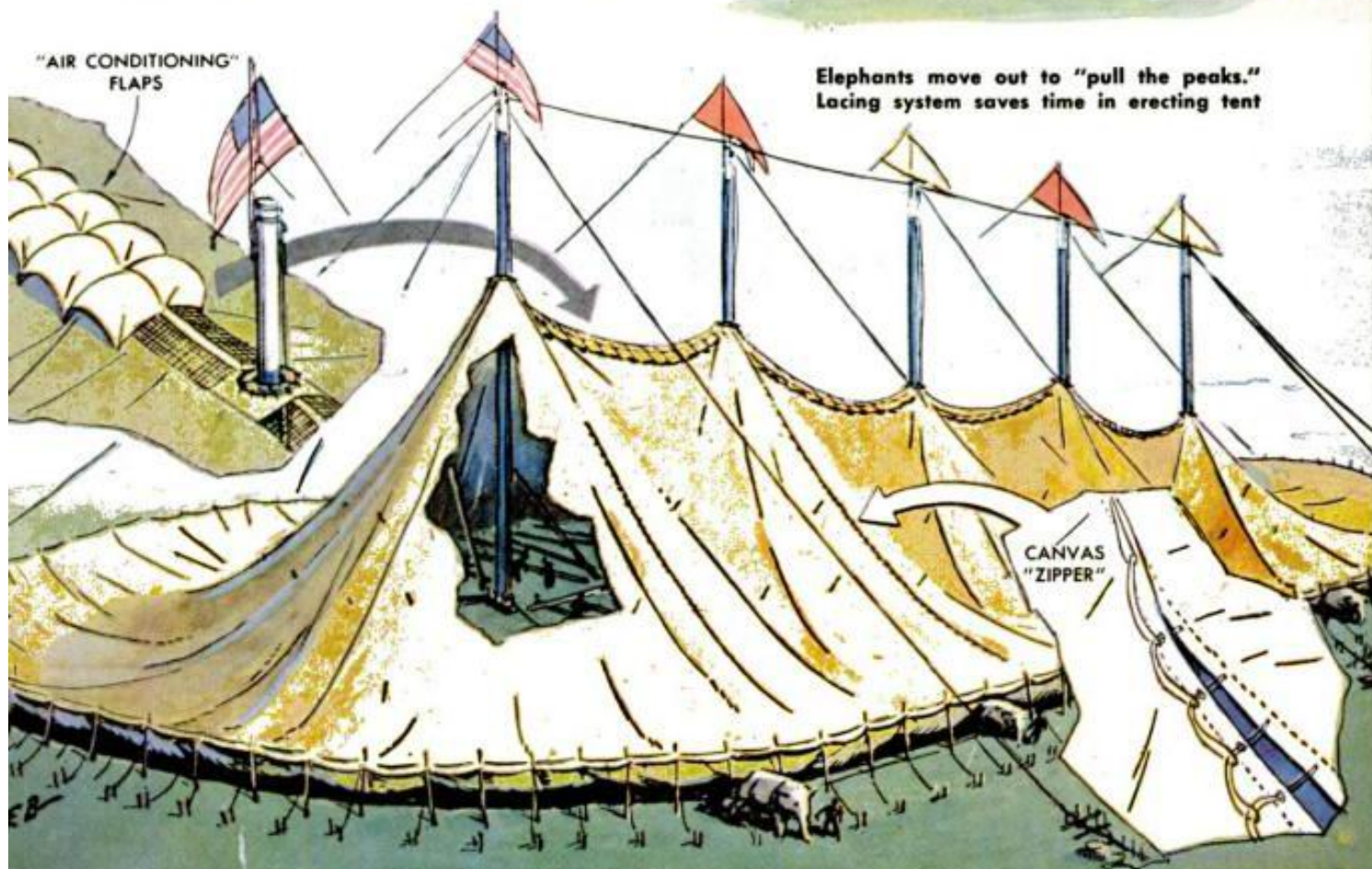
The gaudy trains themselves are a spectacle to tingle the spine of boy or man. Of

Below, tough old elephant moves sedately beneath the sagging canvas, pulling the quarter poles upright



"AIR CONDITIONING" FLAPS

Elephants move out to "pull the peaks." Lacing system saves time in erecting tent



CALLIOPE, BLACKSMITH SHOP, SANITATION TRUCK, BAND, STAKE DRIVERS



BIG TOP POLE WAGONS, STAKES, 20 TONS OF CANVAS



the 69 railroad cars in the three trains, 49 are superlong (72-foot) flatcars. On these flats are 191 garish wagons, anchored end to end. Spotted strategically among the wagons are 27 "cats" and farm tractors which will pull them down the ramps.

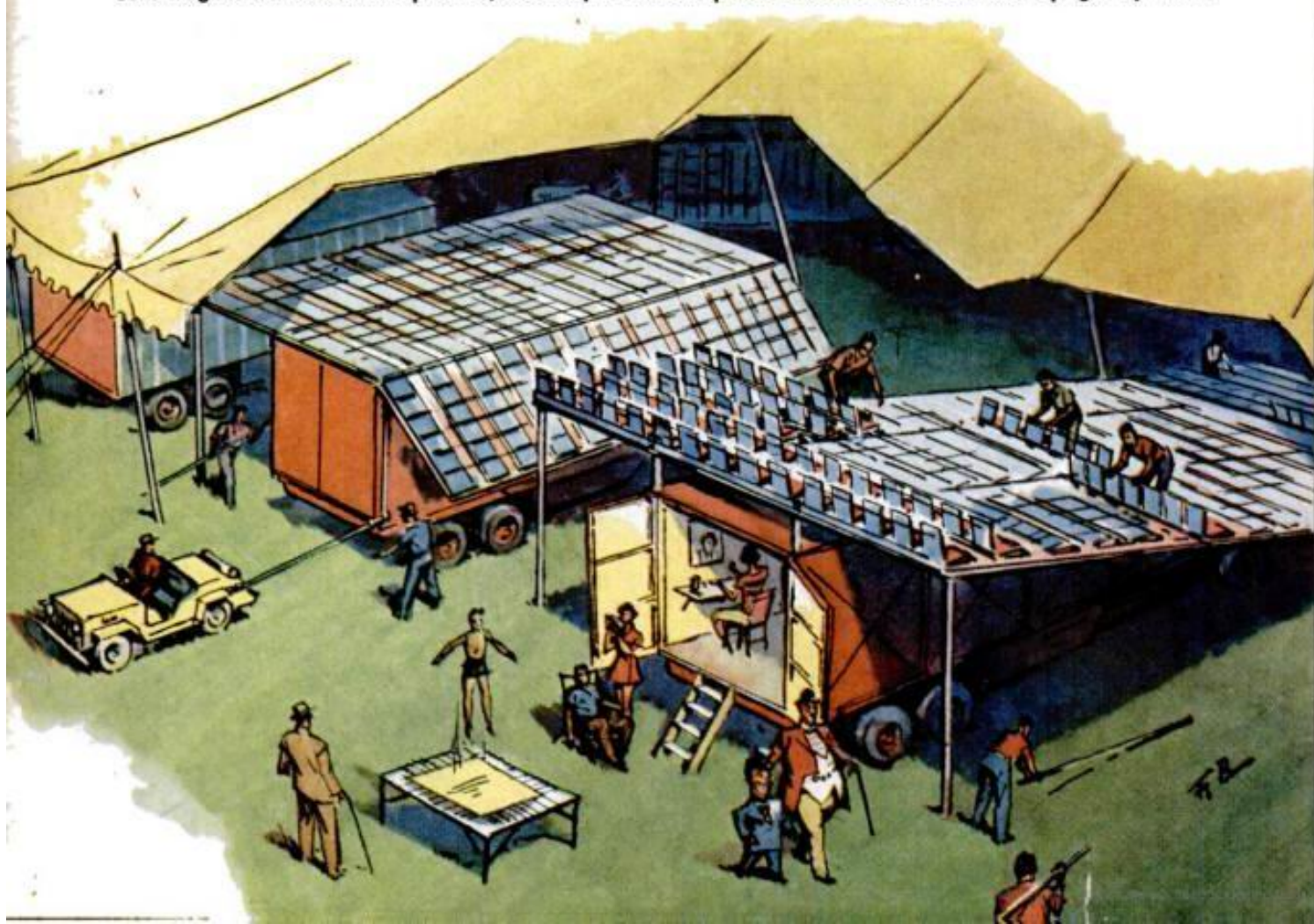
In *The Flying Squadron*, first to pull into the siding, Morgan and trainmaster Paul J. McClane have three horsecars (with folding stalls for 96 horses), two big stockcars (containing 144,000 pounds of elephant) and a parade of wagons containing the menagerie, kitchen, cookhouse, blacksmith shop and other service departments.

Close on the caboose of *The Flying Squadron* rolls the second section toting the big top itself, and bringing up the rear in the third section are 16 of the 26 seat wagons which soon will erupt into a huge amphitheater. Scattered throughout the three sections are 23 coaches; once Army hospital cars, they're now air-conditioned homes for circusfolk.

Gen. mgr. Arthur M. Concello, Morgan's boss, has a working crew of 1400 troupers, organized right down to the Tinytown Midgets, to erect the circus with the precision of an assembly line. Coordination is the secret of the circus' mobility. The show-folk are divided into special working crews, from property department to stables, the big canvas department to the iceman, the usher department to the veterinary. There's even—believe it or not—a chameleon department, highly organized and staffed with "bug men" assigned the sole responsibility of feeding, packing, moving, unpacking and hawking their miniature dragons through the big top daily.

Morgan finally takes pity on the kid at his heels and gruffly sends him off to find George Werner, canvas boss. In his search for Werner, though, the lad is delayed by a gang of "razorbacks" unloading the train. Along the tracks huffs a switch engine, cutting *The Flying Squadron* into two parts.

Seat wagons are hauled into position, their flaps cranked up and the 8000 seats slammed upright by ushers



and within the next 12 hours the world's largest land-traveling restaurant will serve 4200 top-notch meals to the "kinkers," razorbacks, performers and workers of the show.

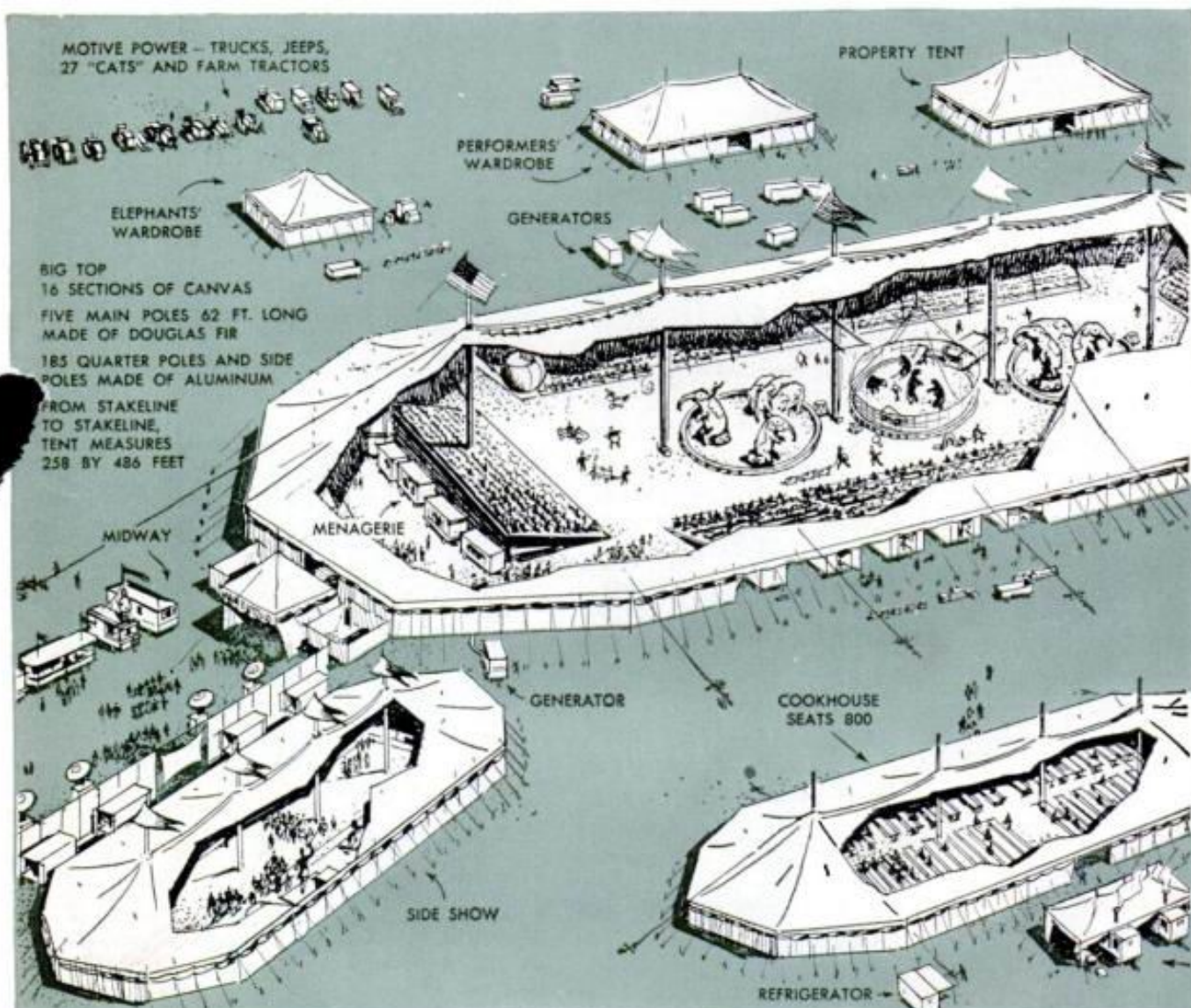
With *The Flying Squadron* unloaded, the second section is switched into position and split at the run cars. Off the train roll wagons bearing the big top itself, largest tent on earth. Over on the grassy lot Morgan has measured to the inch the exact location of each of the five main poles, for the "top" shrinks or stretches as much as five feet in either direction, depending upon the weather. Today he has marked off a huge oval stake line measuring a thumping 486 feet long and 258 feet wide, an area more than twice the size of a football field.

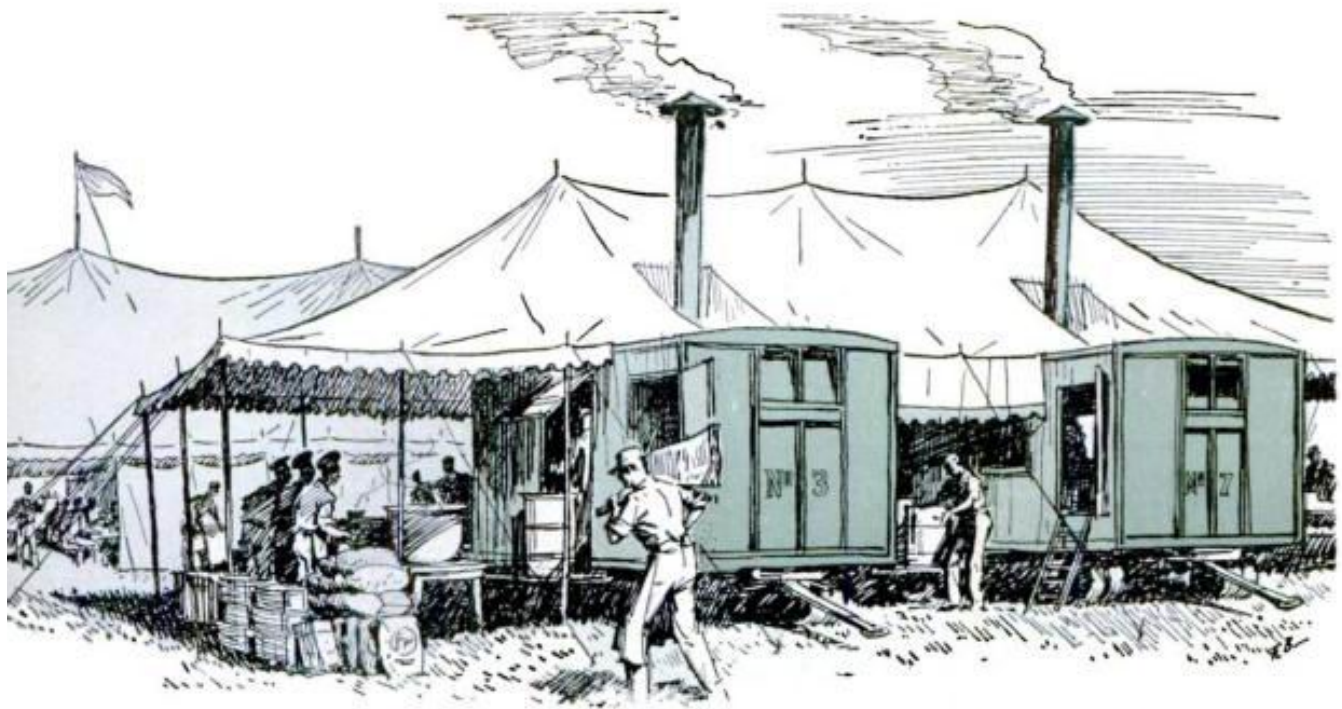
Around the perimeter of this oval crawl two huge stake drivers, one mounted on a converted Army half-track (the flashing sledges of yesteryear have all but vanished in the mechanization of today's circus). Two miniature pile drivers on the rear of the vehicles beat an unending tattoo, slamming the four-foot stakes into the

ground. And down the center of the oval marches a smaller stake driver, mounted on a Jeep, which pounds home the stakes that hold the big center poles in place.

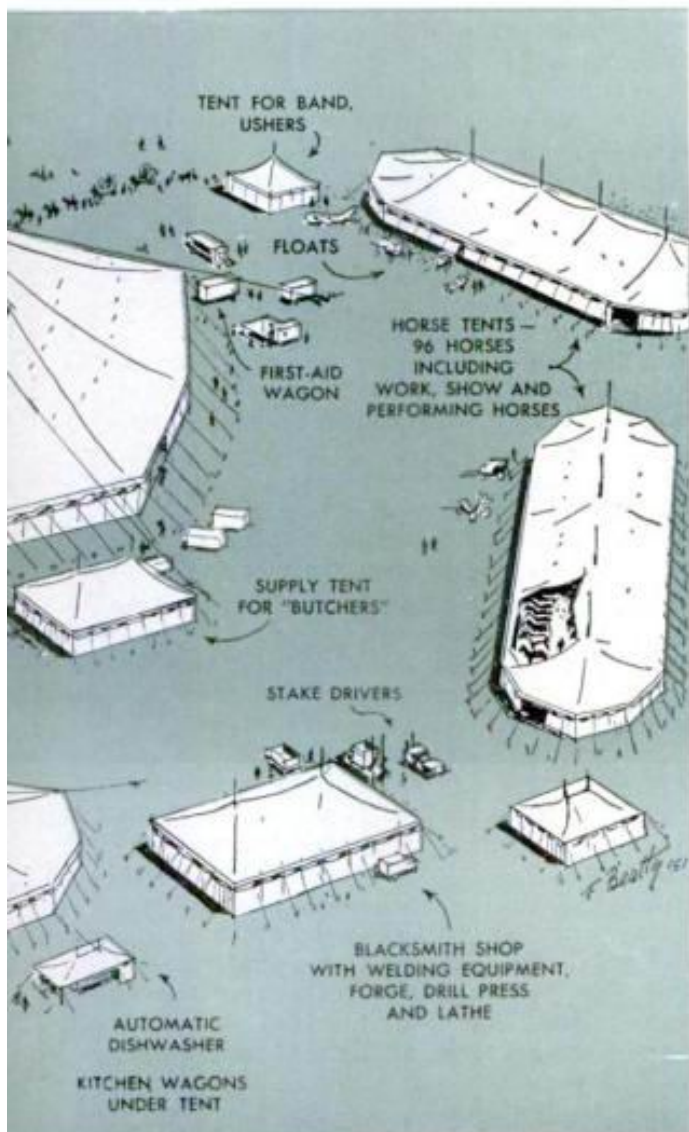
Now along the center line rolls the long pole wagon. As it arrives at each position, one of the five 62-foot main poles teeters off onto two crossarms which cradle it with the base just off the ground, the top several feet in the air. A crew of canvasmen slips a three-foot bale ring onto the bottom of the pole. Soon this ring will rest at the very top of the vast tent, supporting not only the canvas itself but much of the rope and tackle that rig the big top. Meanwhile 185 aluminum quarter poles and side poles thud to the ground all over the staked-out oval.

Number One, the first pole up, is the key to the entire top; it helps raise and lower the others, gives canvas boss Werner a hook high in the sky. First, though, it must be pivoted into place. A 2½-inch hawser, fastened to the top of Number One, runs out to the edge of the oval where it's tied to a heavily staked block and tackle. As a





Kitchen wagons, with tent pitched snugly over them, contain two oilstoves which turn out 4200 meals a day



cat sputters into position and picks up the rope, an undercurrent of tension, a half silence, seems to fall across the lot, for this is the one ticklish job of raising the big top each day. The cat claws forward and Number One pivots slowly and regally into the air, swaying now and then, guy lines jerking it back on course. When it stands straight and true, an American flag flutters up toward its peak. Though no one says a word, the kid watching from the side lines has a feeling the circusfolk have uttered a vast, collective sigh.

Meanwhile, under Werner's sharp eye, the 76,000 yards of flameproof canvas have been dropped piecemeal around the oval. The vast cloth roof is bright-new when the circus leaves winter quarters each spring. By midsummer it's faded and patched.

The kid by now has found Werner and begged a job on a canvas crew. Under the rough direction of the crew boss, the men attack one of the big pie-wedge sections, unfolding it, dragging it into position, then lacing it to the adjoining section. Three canvasmen finally strap the tent to the bale rings at the bottom of each pole. Then the kid tags after the men as they move off the canvas, where, emulating them, he grabs a guy line, holding in his hand a few inches of the 73 miles of rope that hold up the circus.

Werner waves his hand in an almost unnoticeable gesture, an order that somehow flashes instantly around the oval. Workers, moving as one man, slip the side poles into

(Continued to page 220)

Typical "Yankee Robinson" layout steers spectators along the midway at far left, then past menagerie into big top. The rest of the layout is the "back yard" for exclusive use of performers and workers

THE INDYTECH 500

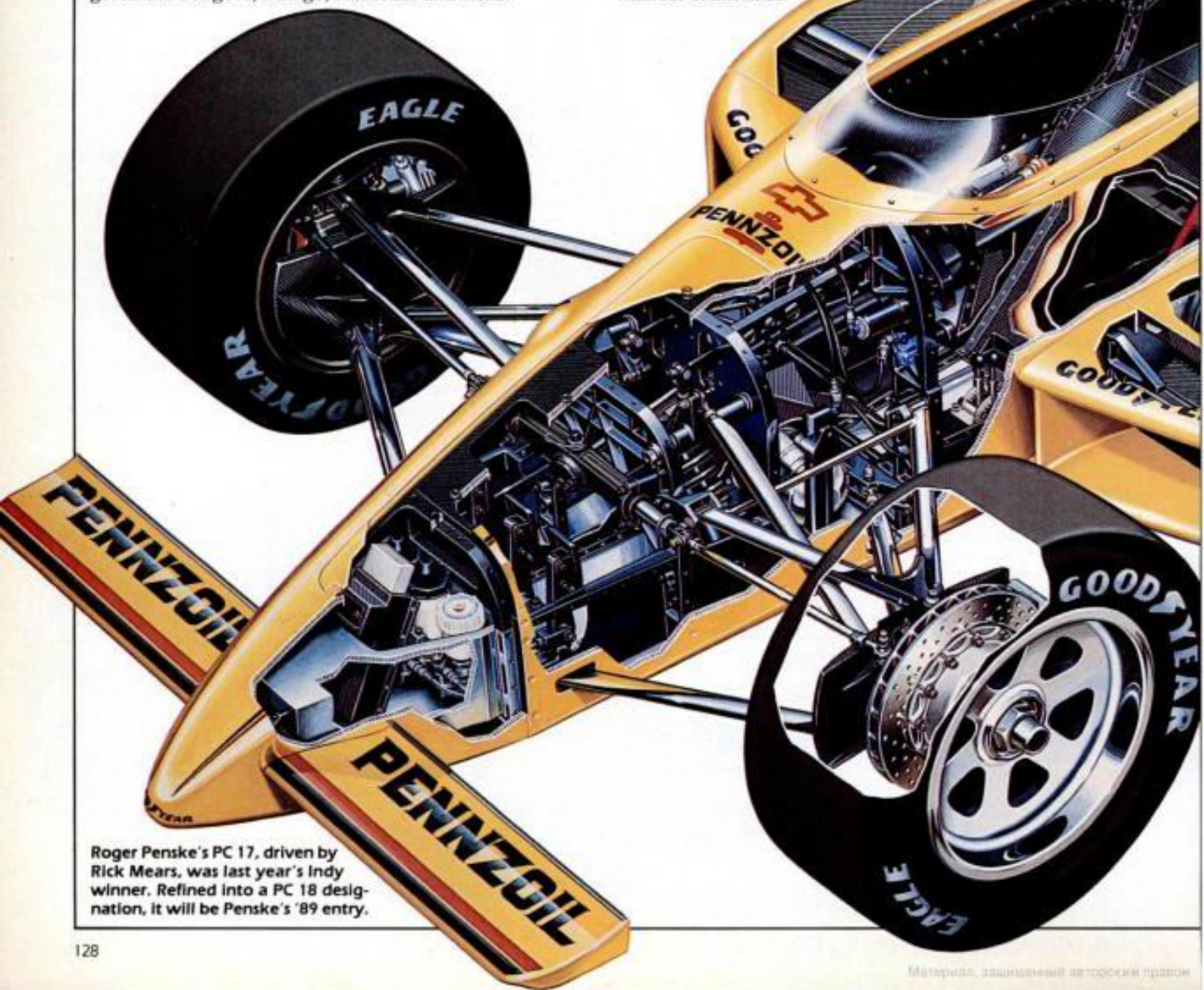
New technology takes the flag at the old Brickyard.

BY PAUL STENQUIST

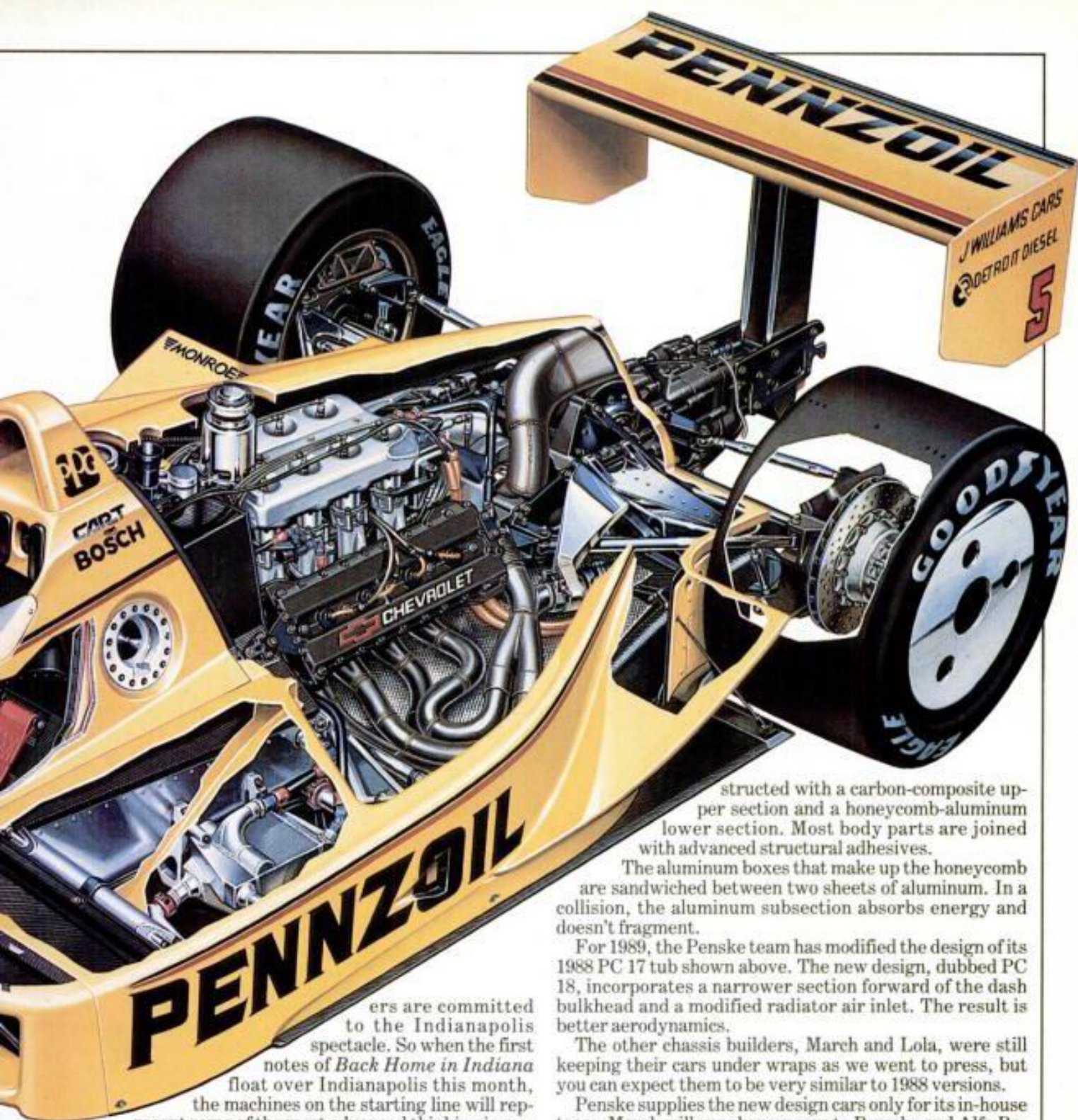
IT WAS AN ASTOUNDING 76 years ago that a 4-valve-per-cylinder, double-overhead-cam Peugeot engine ran away from the Indy 500 field. That powerplant—the grandfather of modern racing engines—serves as a ghostly reminder that Indy was once the technological showcase for the automotive world. An event of international significance, the race was a proving ground to Peugeot, Delage, Mercedes and more.

Over the years both the international flavor of the 500 and the sophistication of its hardware have come and gone. At times the technology was inspirational, at other times it fell short of what could be seen in Grand Prix racing. The difference in mechanical sophistication was usually a matter of cash flow. When the automakers were interested, money poured in and the technology soared.

At the moment, a number of automak-



Roger Penske's PC 17, driven by Rick Mears, was last year's Indy winner. Refined into a PC 18 designation, it will be Penske's '89 entry.



ers are committed to the Indianapolis spectacle. So when the first notes of *Back Home in Indiana* float over Indianapolis this month, the machines on the starting line will represent some of the most advanced thinking in motorsports. And with Porsche, Alfa Romeo and England's Judd every bit as involved as Chevrolet, Ford and Buick, the flavor will be decidedly international.

While there is variety in terms of the engine builders represented and the powerplants used, most 1989 Indianapolis-type race cars are similar. But slight variations and seemingly small ideas can often make a big difference on race day.

The basic Indy car incorporates a monocoque body/chassis unit. There are no frame rails. The bodywork—augmented by the drivetrain components bolted to it—is the structural backbone.

Today's Indy car body units are formed of two materials: carbon-composite plastic and aluminum. Exterior body panels are formed of the carbon composite. The tub, which is both body unit and primary structural member, is con-

structed with a carbon-composite upper section and a honeycomb-aluminum lower section. Most body parts are joined with advanced structural adhesives.

The aluminum boxes that make up the honeycomb are sandwiched between two sheets of aluminum. In a collision, the aluminum subsection absorbs energy and doesn't fragment.

For 1989, the Penske team has modified the design of its 1988 PC 17 tub shown above. The new design, dubbed PC 18, incorporates a narrower section forward of the dash bulkhead and a modified radiator air inlet. The result is better aerodynamics.

The other chassis builders, March and Lola, were still keeping their cars under wraps as we went to press, but you can expect them to be very similar to 1988 versions.

Penske supplies the new design cars only for its in-house team. March will supply new cars to Porsche and Alfa Romeo teams exclusively. Lola will probably produce at least 35 T8900 cars for the other teams.

All cars will be fitted with a pushrod and rocker-type suspension system. This style of suspension has been in use for at least five years now, but every season sees some refinement. In a pushrod and rocker system, the wheel is suspended from the tub by means of two wishbones. Unlike a passenger car, the spring and damper are not mounted on a wishbone. In order to keep these parts out of the airstream, they're mounted inboard and operated by a mechanical linkage system.

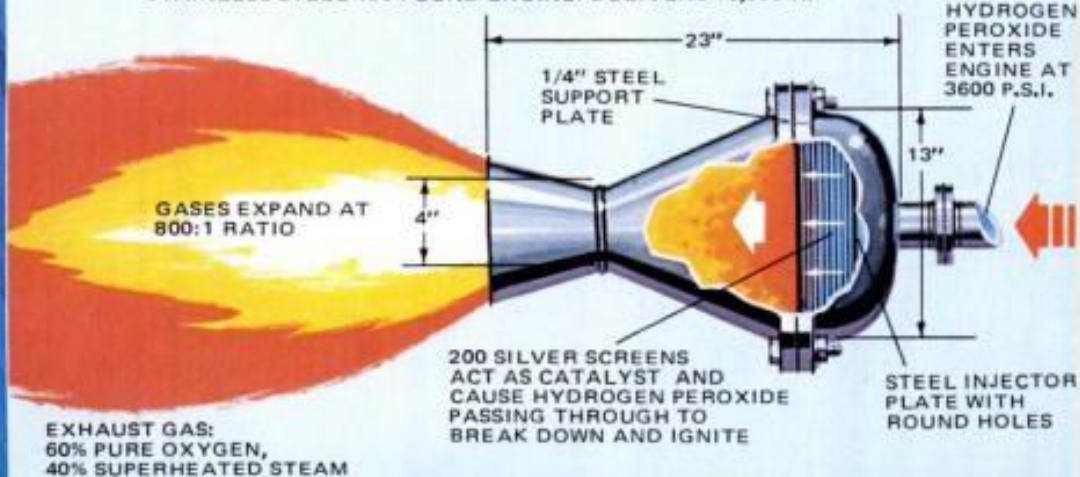
The outer end of each lower wishbone is joined to an upright pushrod which is, in turn, connected to one end of a rocker lever. The other end of the rocker lever is attached to the spring and damper unit. Suspension movement pushes up on the pushrod which pushes one end of the

Airborne at rocket speed.



U.S. Discovery II patented (No. 4,095,549) by Arthur L. Williams

STAINLESS STEEL 150-POUND ENGINE: DELIVERS 16,000 HP



In the Woodruff engine, 200 12-inch-diameter circular silver-mesh screens, similar to window screens, fire off the hydrogen-peroxide fuel to develop the tremendous 8000 pounds of thrust. This "engine" inside its stainless-steel shell weighs only 26 pounds. Pilot's right-hand throttle controls the injection of the fuel/air mixture and its pressure.

Discovery II aims for world record.

core of the 150-pound engine weighs a mere 26 pounds, and is one of the smallest and lightest components of the vehicle. If the engine is working correctly, the critical factor of the rocket boat's success depends on the air-pressure force feeding the hydrogen peroxide to the silver-mesh-catalyzing screens in the engine that create the propelling explosion. This is no back-yard exercise in speed. The U.S. *Discovery II* combines the latest in boat and aircraft design in both engine and hull.

The craft carries two 50-gallon stainless-steel fuel tanks, one mounted for-

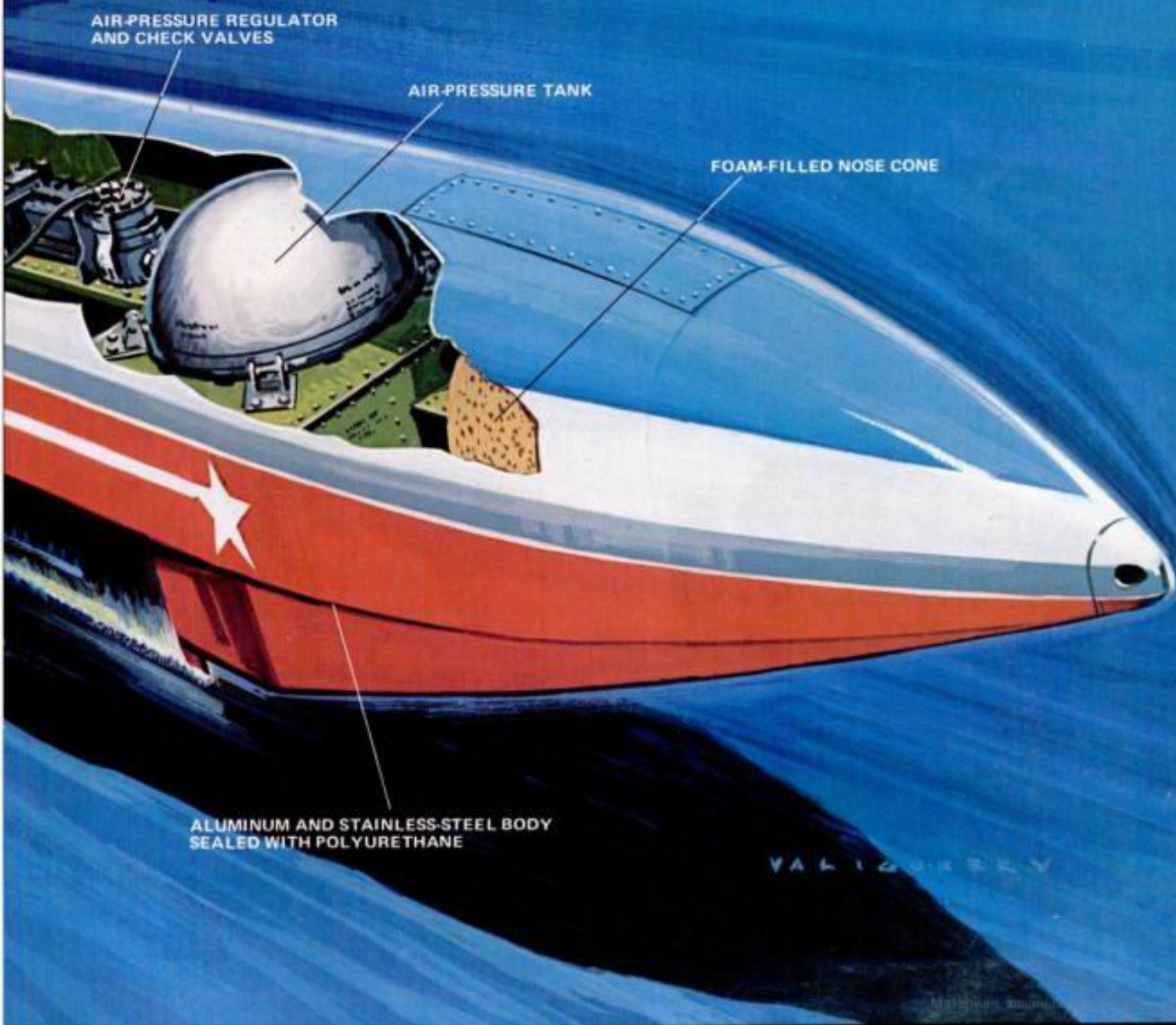
ward of the driver's compact cockpit, the other directly behind the driver. The all-important cylindrical air-pressure vessel is mounted 14 feet from the bow of the boat and will be able to maintain a constant pressure of 3000 pounds per square inch. Between this pressure tank and the fuel tanks are air/fuel regulators, block valve and check-valve system, all of which are pilot-controlled from the cockpit. The right-hand-mounted throttle with which Taylor will turn up the boost also feeds information to three separate gauges that monitor the air/fuel mixture and pressure. All fuel lines and fittings are of aircraft quality and

designed for the safety and protection of the pilot.

The steering system contains a rudder that sits in the water, as on any conventional boat, and also an aircraft-type steering rudder on the vertical stabilizing tail, rising 9 feet above the water. When *Discovery II* reaches high speed, it leaves the water, and only a 4-inch extended skeg below the boat's transom remains below the surface as a fixed guidance device. With all conditions right, everything else is in the air and the boat is a rocket-powered missile with essentially unlimited top speed under proper smooth-water conditions.

Once all this gets moving, it gets

(Please turn to page 158)



HOW TORNADO LABS TAME GIANT TWISTERS

Scientists on several fronts are closer than ever to unraveling the mysteries inside nature's monstrous funnels.

by Franklynn Peterson
and Judi R. Kesselman

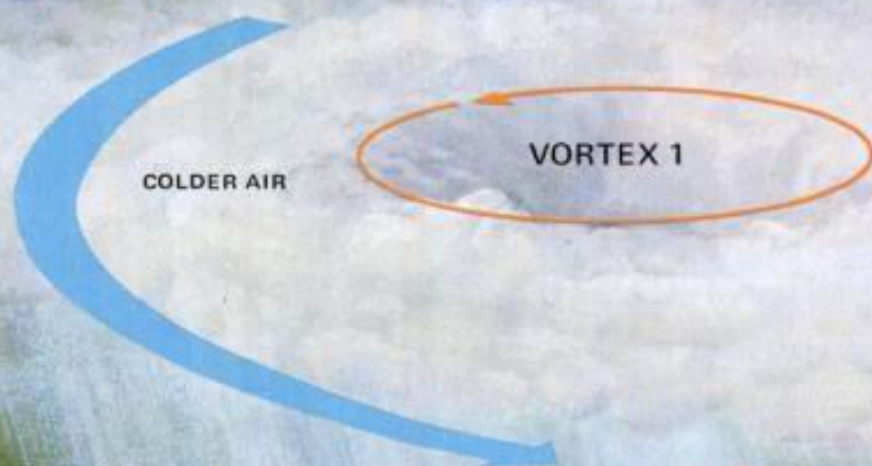
Television newsman Wally Hubbard was driving back from Muncie, Ind., where he'd bought a weather-channel crystal for his scanning receiver, when he heard on the radio that police had spotted a tornado nearby.

"At that moment, the hail was falling so hard on my car, it was like sitting inside a corn popper," Hubbard recalls. "But I stopped anyway and looked out the window toward the south—and there was the tornado. I did what any newsman would do—I grabbed the old windup Bolex movie camera out of the back seat and started shooting." He got off four 30-second bursts before the tornado disappeared.

Hubbard's two minutes of film gave tornado experts their first conclusive evidence of something they had suspected for many years. In his frames, the main funnel divided into four

Tornadoes are spawned in thunderstorms when fronts collide. Shown here in simplified form, a typical big tornado system comprises a slowly circling parent tornado cyclone and two main vortices, resembling wheels within a wheel. Vortex 1, in cool air, spins harmlessly up near cloud ceiling. Vortex 2 has picked up enough energy in warm air at southeast section of

parent cyclone to reach the ground. There, it has divided into still-smaller vortices. Parent cyclone will soon steer Vortex 2 back toward cool air, where it will shrink up into the cloud. Then, Vortex 1 will touch down. Purdue scientists theorize that the up-down movement of dangerous vortices causes notchlike paths of destruction that follow the worst twisters.



RAIN ZONE

PATH UNDER
VORTEX 1

AREA DAMAGED
BY VORTEX 1

PATH UNDER
VORTEX 2



PARENT
TORNADO
CYCLONE

1/2 TO 2 MILES

VORTEX 2

WARMER AIR

40 MPH FORWARD
MOVEMENT TO
NORTHEAST

1000-1200 FT.
TO BASE
OF CLOUD

75 MPH
UPDRAFT

HAIL ZONE

AREA DAMAGED
BY VORTEX 2

PM art: Dean Ellis

MARINE



SuperOutrigger: Smooth sailing in rough seas

Since the early days of civilization, Hawaiian seafarers have been putting outriggers on their canoes to keep them from tipping over. Now a modern Hawaiian inventor, Nathan I. Daniel, has applied the idea to a large, oceangoing craft called a SuperOutrigger. Its elevated hull rides above the waves on a central, main pontoon, counterbalanced by a smaller outrigger pontoon. The result, says Daniel, is a highly stable platform that glides smoothly through heavy seas with virtually no

pitching, rolling or pounding. Besides its tip-proof safety and gentle handling, other advantages are less power-robbing drag compared to a deep displacement hull; simpler, cheaper construction; and more economical operation.

Initially, the SuperOutrigger will be built as a 320-foot-long car/passenger ferry for fast travel over the often rough waters between the Hawaiian Islands. But the basic design will lend itself to other configurations as well, such

as a workboat for servicing offshore oil rigs, a seagoing heliport for search and rescue missions, and a flat-deck freighter for containerized cargo. Smaller versions could also become a supersafe pleasure cruiser or a party boat for deep-sea fishing.

Twin engines, one in the after end of each pontoon, are said to permit much greater maneuverability than a conventional hull because their propellers are set wide apart and are fitted with controllable-pitch blades. For very sharp turns, one propeller can be reversed as a brake, while the other thrusts forward.

AVIATION

Lifesaving collision alarm

Midair collisions, which have killed about 800 since 1970, should soon be a thing of the past. With a new electronic warning system just approved by the FAA, two airliners on a collision course will be able to talk to each other directly through computers and take immediate evasive action without waiting for a ground controller to spot them and issue verbal commands.

Twin radar beacons on the top and bottom of each airliner scan a spherical field of airspace 14 miles in all directions. These signals, interacting with those from transponders, tell on-board computers the heading, range, speed and altitude of each approaching aircraft. (Present radarscopes show only weather patterns, not contacts with other traffic.) The computers then flash instructions to each pilot by means of lighted arrows on a cockpit display, telling him to climb, dive or turn to the right or left.

The new TCAS (for Traffic Alert and Collision-Avoidance System) has been tested successfully at the FAA's Technical Center in Atlantic City, N.J., and is expected to be operational by mid-1984. It will cost about \$50,000 per unit—peanuts compared to the multimillion-dollar price of a commercial transport or military jet. A simpler version, for about \$2,500, will be available for business and personal aircraft.

UMBRELLA-LIKE RADAR COVERAGE EXTENDS 14 MILES IN ALL DIRECTIONS

THREAT AIRCRAFT WITH BEACON TRANSPONDER

TRANSPONDER SIGNAL WARNS PILOT OF AIRLINER

TOP-MOUNTED RADAR TRANSMITTER

TCAS-EQUIPPED AIRLINER

BELLY-MOUNTED RADAR TRANSMITTER

FLASHING ARROW TELLS PILOT TO CLIMB

VERTICAL SPEED POINTER SHOWS THE RATE OF CLIMB OR DESCENT

COCKPIT WARNING INDICATOR



Close calls (left) won't happen with new anticollision system. Cockpit display (above) warns the pilot to take evasive action.

Editor: Dennis Eskow
Contributors: Sheldon M. Gallager, Jack Hammond, Mort Schultz, Eldonna Fisher, Christopher Swann, Bruce Most, Bernhard J. Hurwood

TECHNOLOGY UPDATE



PM art: Dean Ellis

allowing the vessel to pivot in its own length much like a tracked Army tank. Duplicate sets of rudders in both the bow and stern also aid maneuverability, eliminating the need for expensive auxiliary bow thrusters.

For added safety, the pontoons are divided into a series of watertight compartments. In case of an accidental rupture, several sections can flood without endangering the craft's buoyancy. A 1/6th-scale test model has already proved seaworthy, and construction of a full-scale prototype is expected to begin later this year.



A manned ADV descends into sea (top), its arms worked from cockpit. An above-sea crew (above) guides unmanned model.

Neptune's 'arms'

They can carry a man 3,000 feet below the surface or send a TV camera down 10,000 feet. Once below, their two robot arms, operated by a diver inside the vehicle or by a crew in an above-surface control room, can work on oil wells. These are the Arms Delivery Vehicles, or ADVs, manufactured by Ocean-neering International, a Houston-based underwater service company.

The new ADVs are lowered to the job on a 1½-inch steel umbilical cable. Once at depth, horizontal and vertical thrusters can position it delicately. Without a diver, the equipment sees with pan and tilt video cameras operated from the surface.

During actual work, the force-feedback manipulator arms of the diving bell can push, pull, turn, lift and set down heavy objects. The operator inside the bell or on the surface works the arms with a switch designed by General Electric that uses electronically processed data to give the switch the feel of an object that is doing the actual lifting. This gives the operator a feel for how much force the robot arms should exert. The ADVs have two grabber-manipulator arms that can hold a beam steady and lift objects of up to 900 pounds. The ADV, which has been an experimental vehicle until now, is expected to see service in the Texas gulf by the end of this year.



SPY PLANE FOR NATO

The first NATO squadron of Lockheed-built TR-1 spy planes is being delivered to Alconbury, England, this summer. The first six TR-1s of the 35-plane order were

delivered in June, with three more scheduled to arrive by September. The planes cruise at 430 mph at 70,000 feet. They fly in any weather, day or night.



BAD WEATHER GUARANTEED

Airline pilots are flying Boeing 767s in the foulest weather they've ever seen, but it's very safe. With a Smiths Industries weather radar simulator, a pilot can practice flying through a storm that develops with uncanny realistic speed and true foul-weather readings (left) on the simulator's radar screen.

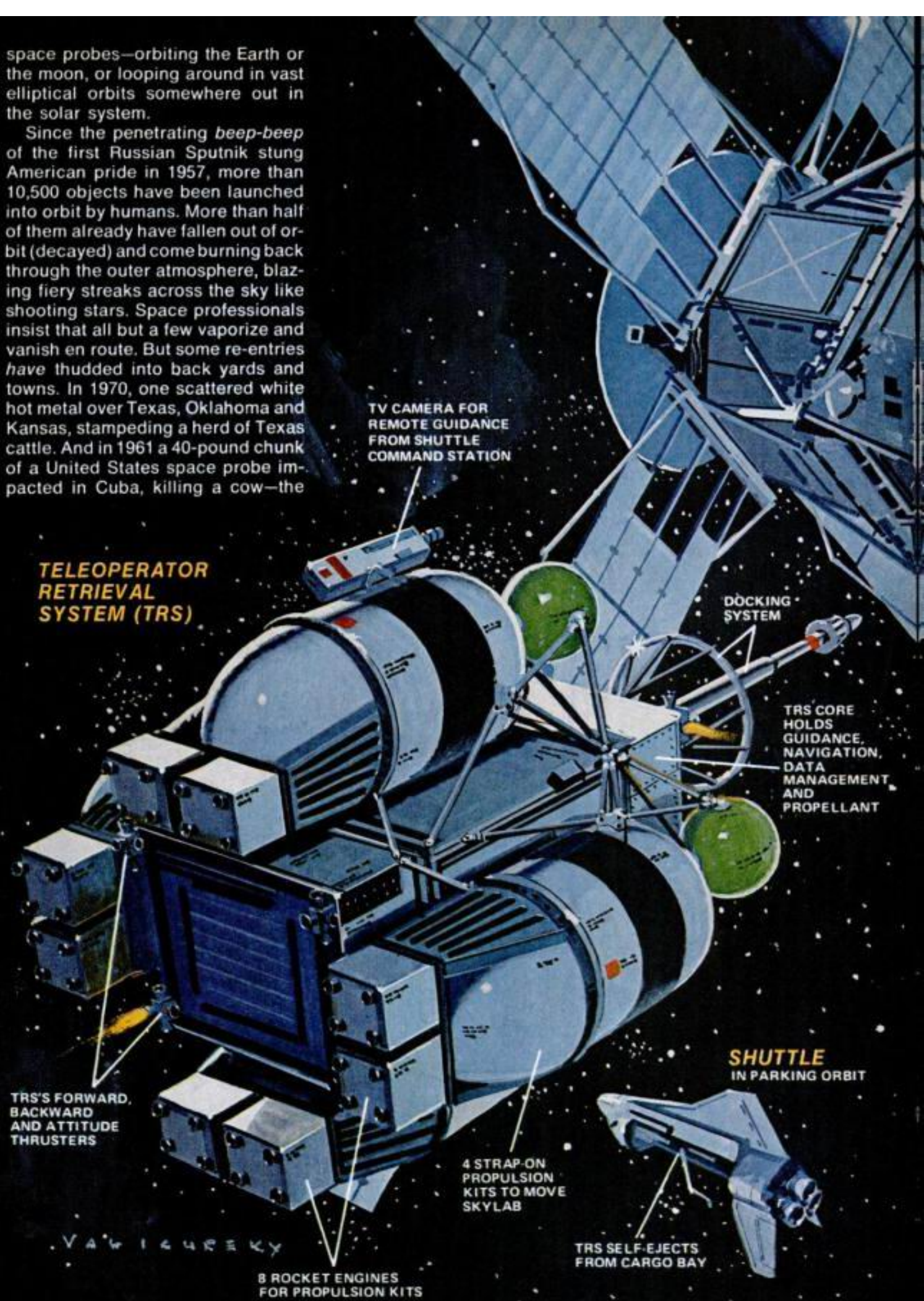


FLAPS UP, DOME DOWN

The latest development in simulated combat flight is the McDonnell Douglas F-15 Eagle simulator. The two-seat cockpit sits under a 40-foot-diameter dome on which training officers can project all sorts of situations from dog-fights to near-ground combat. In addition to training pilots, the simulator is evaluating the F-15's instrumentation for attack-craft duty. That includes electronics to control air-to-air and air-to-ground missiles. The F-15 already is flight-certified with a wide range of advanced-fighter capabilities, including long-range, all-weather radar.

space probes—orbiting the Earth or the moon, or looping around in vast elliptical orbits somewhere out in the solar system.

Since the penetrating *beep-beep* of the first Russian Sputnik stung American pride in 1957, more than 10,500 objects have been launched into orbit by humans. More than half of them already have fallen out of orbit (decayed) and come burning back through the outer atmosphere, blazing fiery streaks across the sky like shooting stars. Space professionals insist that all but a few vaporize and vanish en route. But some re-entries *have* thudded into back yards and towns. In 1970, one scattered white hot metal over Texas, Oklahoma and Kansas, stampeding a herd of Texas cattle. And in 1961 a 40-pound chunk of a United States space probe impacted in Cuba, killing a cow—the



TV CAMERA FOR
REMOTE GUIDANCE
FROM SHUTTLE
COMMAND STATION

**TELEOPERATOR
RETRIEVAL
SYSTEM (TRS)**

DOCKING
SYSTEM

TRS CORE
HOLDS
GUIDANCE,
NAVIGATION,
DATA
MANAGEMENT
AND
PROPELLANT

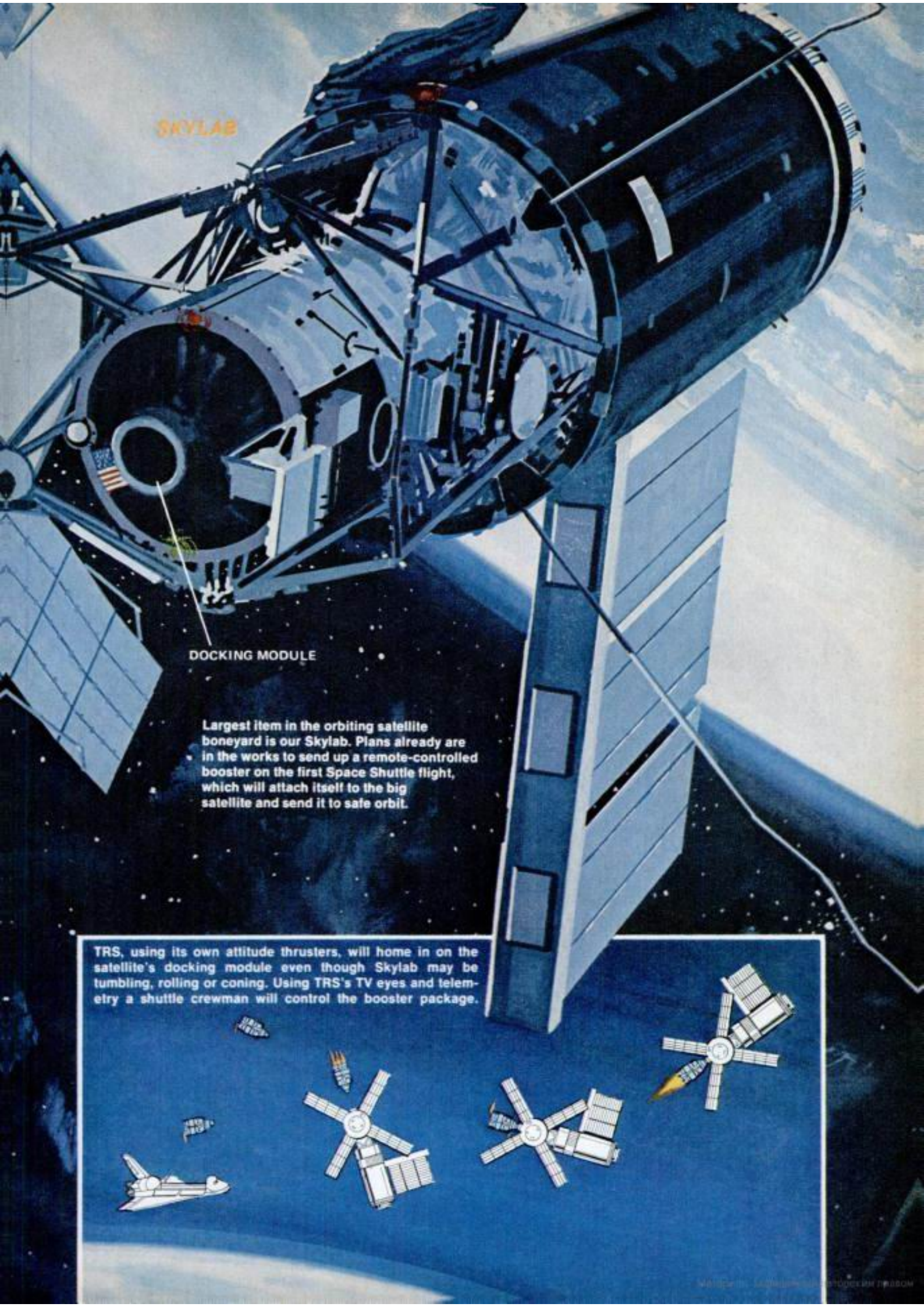
TRS'S FORWARD,
BACKWARD
AND ATTITUDE
THRUSTERS

4 STRAP-ON
PROPULSION
KITS TO MOVE
SKYLAB

**SHUTTLE
IN PARKING ORBIT**

TRS SELF-EJECTS
FROM CARGO BAY

8 ROCKET ENGINES
FOR PROPULSION KITS



SKYLAB

DOCKING MODULE

Largest item in the orbiting satellite boneyard is our Skylab. Plans already are in the works to send up a remote-controlled booster on the first Space Shuttle flight, which will attach itself to the big satellite and send it to safe orbit.

TRS, using its own attitude thrusters, will home in on the satellite's docking module even though Skylab may be tumbling, rolling or coning. Using TRS's TV eyes and telemetry a shuttle crewman will control the booster package.



Of some 10,500 objects launched into orbit by mankind since the Space Age began in 1957, more than half have returned to Earth. Most re-entries go unnoticed.

Our growing junkyard in space

Nearly 4500 man-made objects, from golf-ball size to the 170,000-pound Skylab, were in orbit as of midyear. Between working satellites and plain junk, they form a sizable hazard. Here's what we're doing about it.

by Richard F. Dempewolff

When the bits and pieces of Russia's Cosmos 954 satellite, powered by a nuclear reactor, spattered across the Canadian wilderness last January, a lot of people were considerably shaken. What else "up there" might come cascading down on us?

The fact is that there's a skylful of space trash—as well as useful, functioning satellites and

With land reserves of key metal ores thinning out, nations are gearing up to probe the biggest mine of all—the sea.



Outsized nodule—a freak—is examined by J.L. Shaw, president of Ocean Management, Inc., during operations south of Hawaii. Drillship Sedco 445 (below) got a new hydraulic mast before she adopted her role as a deep-sea mining vessel.



Tapping the world's deepest, wettest mine

by E. J. Lewis

The world's deepest mine, according to the *Guinness Book of World Records*, is the 12,600-foot Western Deep Levels Mine at Carletonville, South Africa. But that's on dry land. Now scientists are preparing to top this feat—in ocean waters nearly *three miles* down. Last February, the *Sedco 445* left Honolulu to take up station in the Pacific

Ocean about 800 miles south of Hawaii. On this voyage, the 17,150-ton drillship would not probe for oil or gas, her usual assignment. This was a mining operation. Plans called for lowering a string of pipe with a sled-like collector at its end. Like a giant vacuum cleaner, the rig would suck up roundish lumps of mineral ore from the ocean floor 15,000 feet below.

With mineral ores on land becoming ever more costly to refine because of poor quality, industrial nations are turning their eyes to the sea—to the deposits that can be dredged from the deepest, wettest mine in the world. The *Sedco 445* operation, conducted by Ocean Management, Inc., is the latest development in an international effort to perfect the techniques and hardware needed to tap the incredibly rich mineral cache strewn over the sea floor in the form of manganese nodules.

Early discoveries

The nodules were actually discovered more than 100 years ago by scientists aboard the *Challenger*, a British ship that made a series of notable oceanographic voyages. Sea-floor samples taken during these explorations contained dark lumps of minerals, first thought to be random, scattered chunks. But after World War II, with the advent of effective deep-sea cameras, researchers could say with certainty that manganese nodules seem to exist in surprising quantities almost everywhere on the ocean bottom.

Most manganese nodules are black, shaped something like a potato and small enough to hold in the palm of the hand. Their surface tends to be rough, and they're porous, often containing as much as 35 percent water. They're spawned from the ocean itself, for the ocean is a mineral broth containing various

Using advanced electronic gear, exploration ship *Valdivia* set stage for successful sea-floor mining operations by mapping Pacific site and plotting bottom hazards.

MINING SHIP

BOOSTER PUMPS ALONG PIPELINE

PIPE STRING

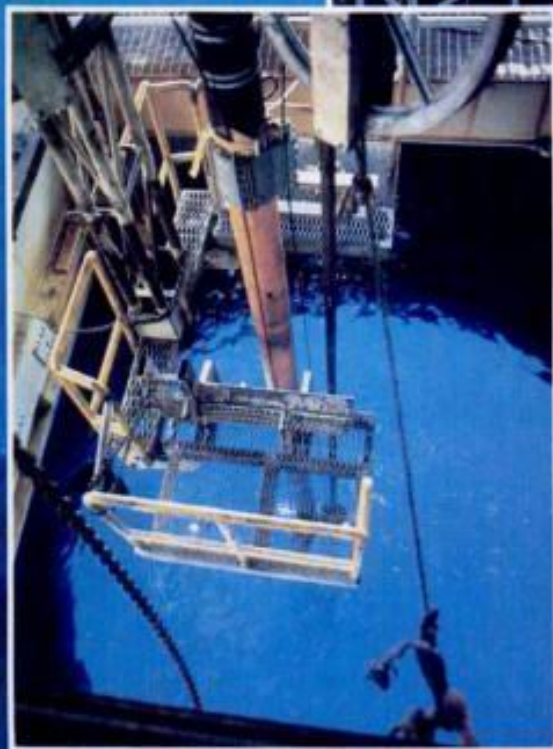
SWIVEL JOINT

FLEXIBLE HOSE

ELECTRIC POWER AND CONTROL CABLES

Because of large 9½-inch pipe needed for mining test, massive hydraulic mast (right) had to be specially built. It has a lifting capacity of 800 tons.

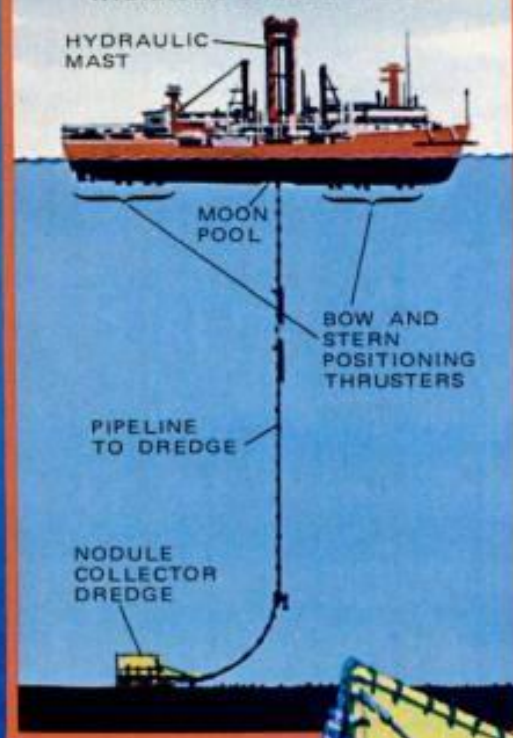
Pipe sections, nodule collector and other gear are lowered to sea floor through "moon pool" well in ship's hull (below).



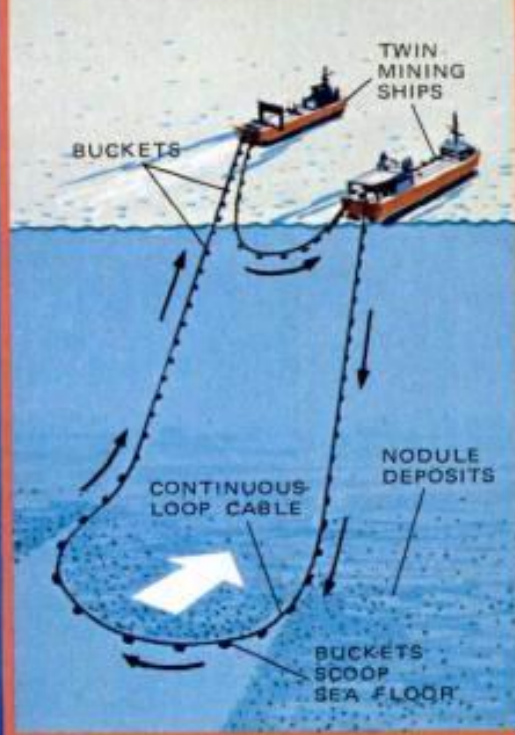
Towed slowly by mining ship riding some 15,000 feet above, sledlike collector scours the sea floor, sucking up manganese nodules like a giant vacuum cleaner.



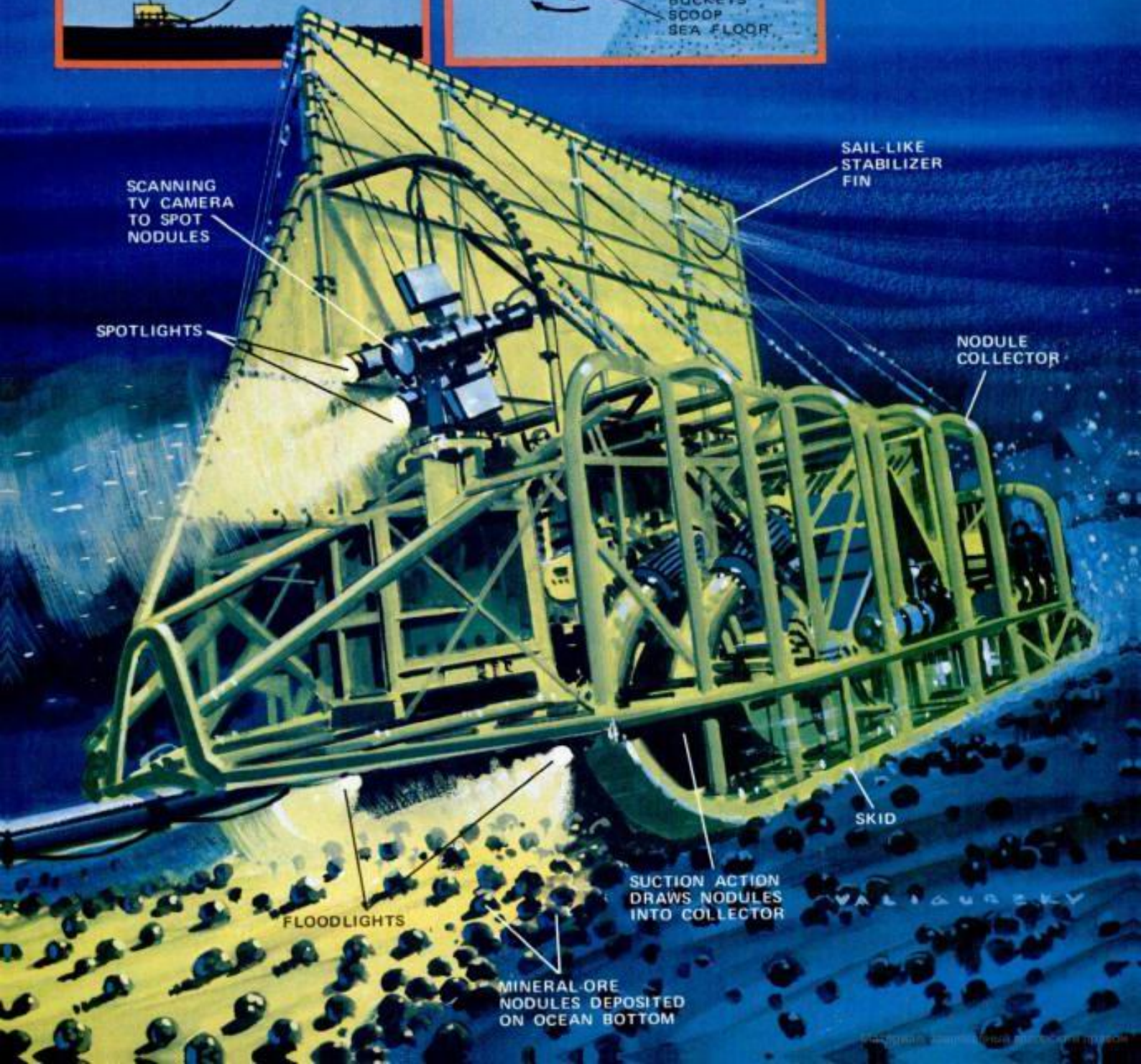
HYDRAULIC DREDGE SYSTEM



BUCKET SCOOP SYSTEM



Bottom collector connected to a long string of pipe (left) is generally favored mining system. Water and nodules can be drawn to surface by powerful pumps or lifted upward by air injected into pipe at various points. "Bucket brigade" system is being tested only on pilot scale. Buckets on long loop of cable strung between ships scrape sea floor, empty contents at surface, then return to bottom in continuous, rotating cycle.



**GRAND
DESIGN**

LUXURY
CABINS

STANDARD CABINS

PASSAGEWAY

BREAKFAST NOOK

STEERABLE
TRAILER AXLE

GENERATOR &
ACCESSORIES
COMPARTMENT

ENGINE
COMPARTMENT

Articulated design makes the 59-ft. bus very maneuverable. Dinette converts to bunk in luxury cabin.

Breakfast nook is complete with microwave oven; cabin attendant is cook for breakfasts, light snacks.

Sightseeing is top attraction; but stereo movies are also on tap. The bathroom's snug, but fully equipped.



HAVE ROOM, WILL TRAVEL

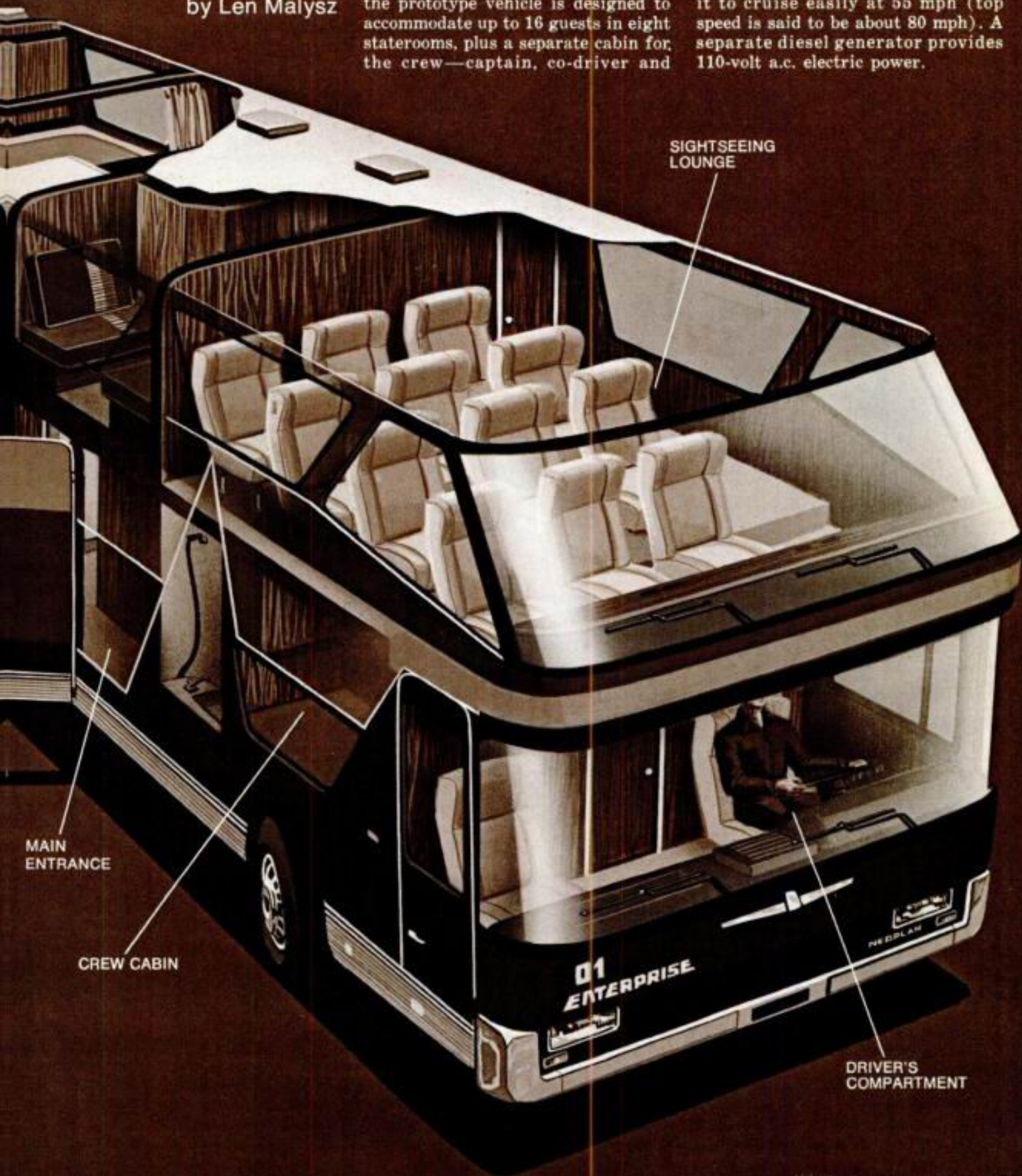
The ultimate tour bus is a hotel that checks out with you.

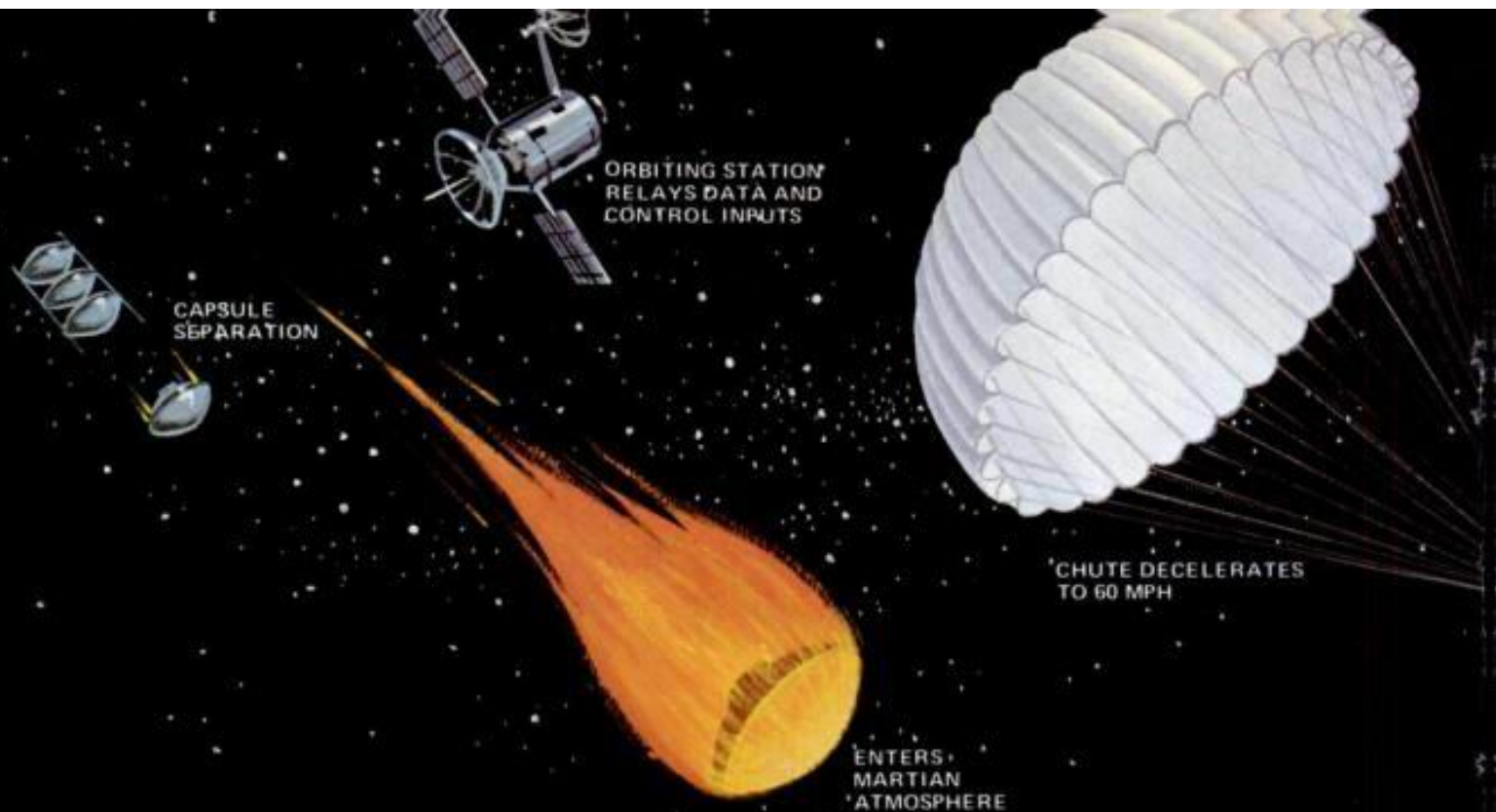
by Len Malysz

No, it's not a movie set—the 59-ft. articulated bus that's called a Car-O-Tel really exists. Commissioned by Dutch entrepreneur Fred Nauta, the prototype vehicle is designed to accommodate up to 16 guests in eight staterooms, plus a separate cabin for the crew—captain, co-driver and

cabin attendant.

The European-built colossus weighs 26 tons and is powered by a 320-hp Mercedes-Benz engine which enables it to cruise easily at 55 mph (top speed is said to be about 80 mph). A separate diesel generator provides 110-volt a.c. electric power.





As conceived by Jet Propulsion Laboratory under a NASA research contract, an RPV could actually fly on Mars, even though at the surface the Martian atmosphere's density is only 1 percent that of Earth's. (Martian gravity is only three-eighths as strong as ours.)

As many as four of the aircraft, powered by hydrazine engines that do not breathe air, would be delivered by a spacecraft which would remain in orbit as a relay station. Entering the Mars atmosphere from orbit, the collapsed aircraft would be

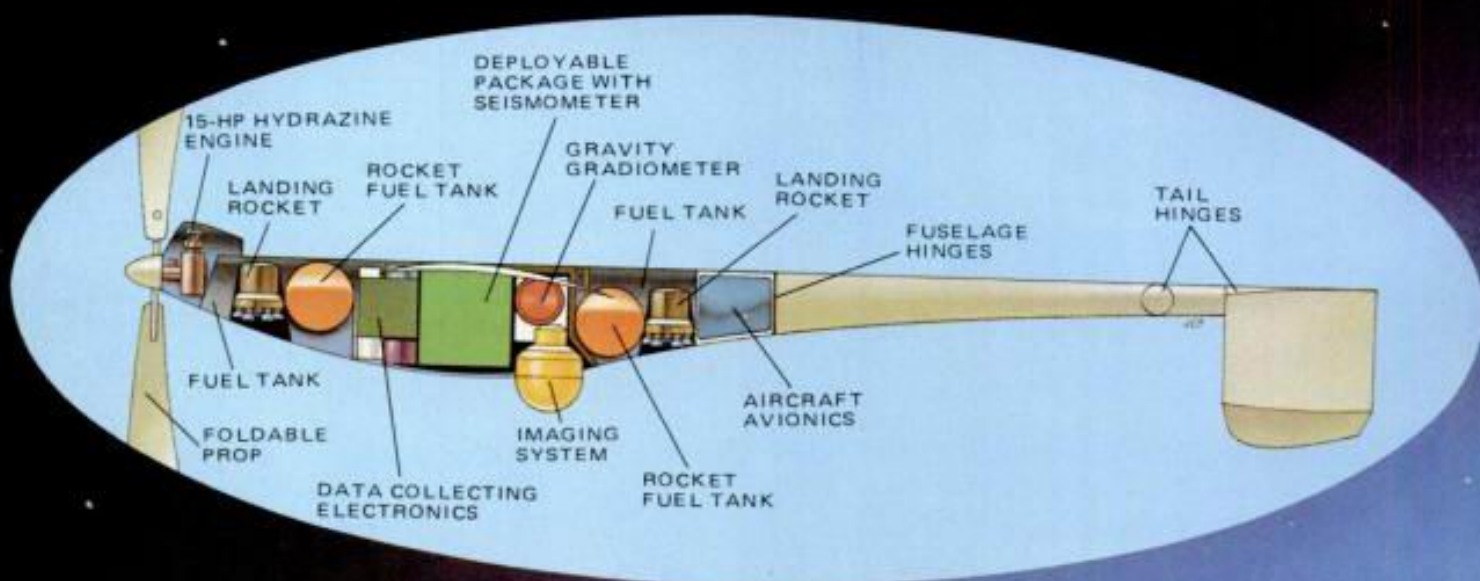
protected by Viking-type capsules; a parachute would slow the capsule to about 60 mph for capsule jettison, followed by unfolding and deployment of the aircraft into a vertical dive.

Pulling up at a preprogrammed rate, the aircraft would fly at speeds between 125 and 225 mph in "air" at the equivalent density of altitudes over 100,000 feet on Earth—although the flight regime on Mars would be carried out at much lower actual altitudes.

Two versions of the Mars airplane could

be built—one able to land and take off again with rocket engines, as shown below; the other a straightforward "cruiser" that could cover as much as 6000 miles in 30 flight hours before crashing. Navigational and terrain-following electronics would be preprogrammed for specific flight paths, since radio signals from Earth would take excessive time for total flight control.

Highly detailed pictures, atmospheric and geologic data would be relayed back to Earth.





CAPSULE
JETTISON

AIRPLANE
DEPLOYED



To test oblique wing flight concepts, NASA contracted for rotating-wing RPRV powered by 4-cylinder, 90-hp engine driving shrouded prop.



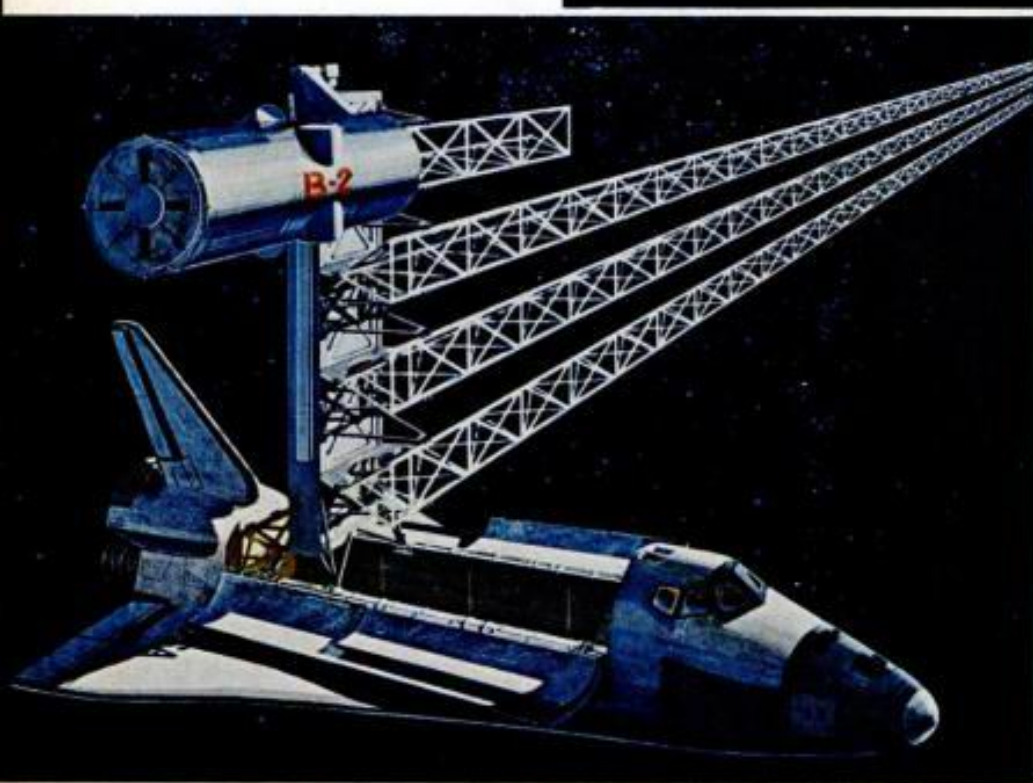
Stall characteristics of Air Force F-15 fighter were tested in a remotely piloted, $\frac{1}{10}$ -scale model of the plane, launched from a B-52.

A year from this month a squat, stubby, 75-ton spacecraft with trimmed-down excusers for delta wings will be tipped up on its tail on a NASA-Kennedy Space Center launch complex. At the end of a standard countdown, the ugly duckling of the Space Age will blast off missile-fashion and rocket itself in an Earth orbit some 100 miles in space. There, it will circle the Earth as a space station satellite for a month or more. Then, missions accomplished, it will descend into the atmosphere and use its wings to make a proper runway landing—a little “hot,” perhaps, but otherwise like any standard, fixed-wing airplane.

If all goes well, the Shuttle Orbiter's trial run, scheduled for the fall of 1979, is expected to signal the start of regular round trips to and from Earth orbit at less than one third the current cost of such missions.

While the United States has not yet committed funds beyond that first Shuttle flight, fully developed plans are in the mill for an eventual fleet of five such spacecraft, leaving weekly, to lift passengers and pay-

Mining asteroids in space for raw materials to build space stations is new goal in space technology. Painting shows a mass driver used as tug to tow an asteroid to Earth orbit. There, mass driver will fire mined ore to building site. Below, factory and Shuttle Orbiter fabricate a satellite component.



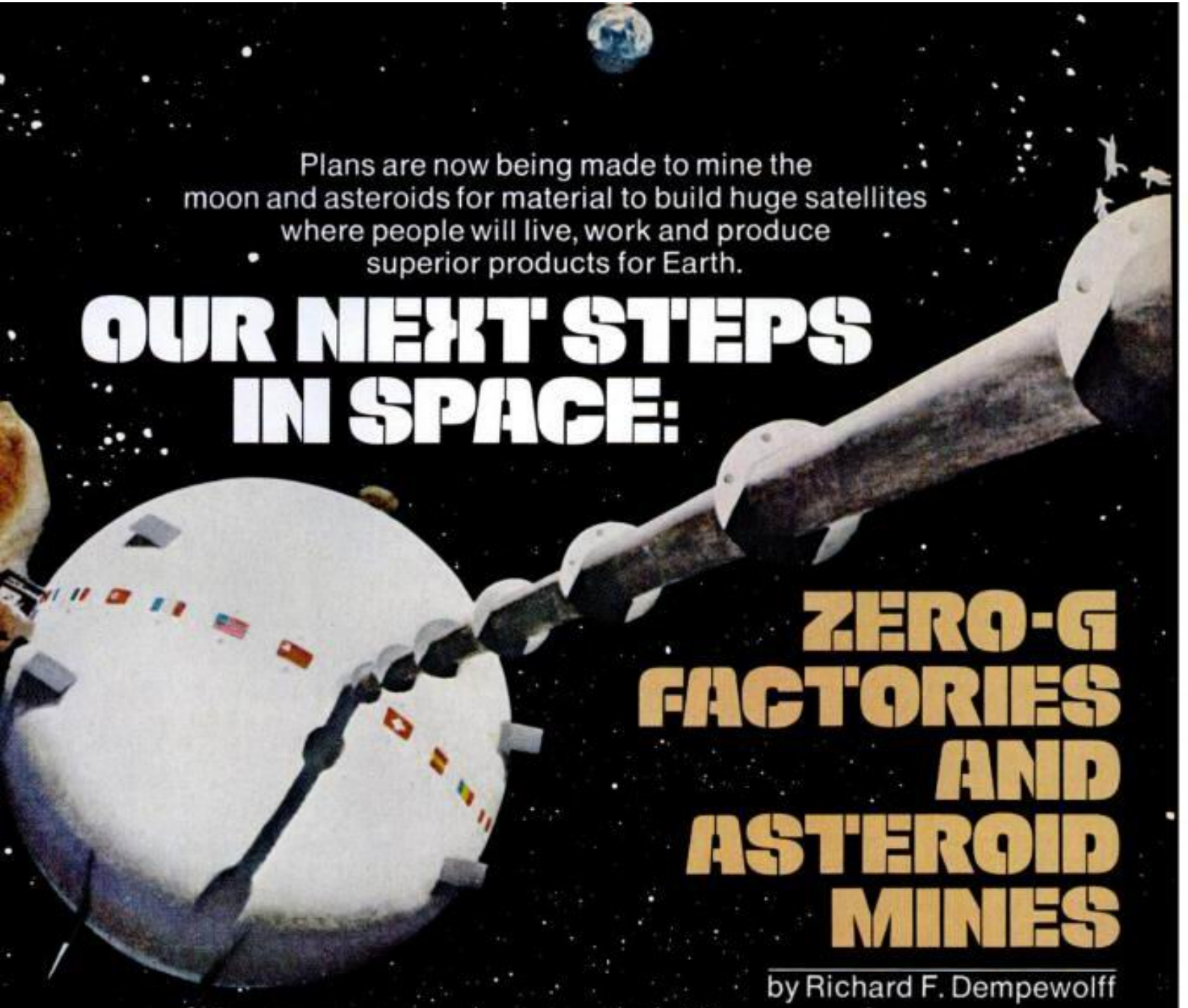
load cargoes into orbit for a wide variety of mind-boggling space projects. Objectives already call for the Shuttle to deploy, service and repair communications and Earth-sensing satellites. Other missions will involve experiments for orbiting space labs, including manufacture of special electronic, medical and pharmaceutical supplies; mining of the moon, collection and

Plans are now being made to mine the moon and asteroids for material to build huge satellites where people will live, work and produce superior products for Earth.

OUR NEXT STEPS IN SPACE:

ZERO-G FACTORIES AND ASTEROID MINES

by Richard F. Dempewolff



mining of asteroids; parts manufacturing and assembly of test prototypes for vast solar energy satellites in geosynchronous orbit that will beam power to Earth by microwave; space habitats and space hospitals for workers; even tourism and recreation (May '75 and June '77 PM).

Science fiction? Hardly. Already manufacturing experiments per-



Artist's concept shows a beam-builder at work assembling a final longitudinal member for a Solar Space Power Satellite.



formed on the Apollo-Soyuz flight, in Skylab and on other missions have demonstrated the advantages of fabricating products demanding high purity and structural conformity in the near-perfect vacuum and zero gravity of space—conditions that can't be reproduced on Earth.

Prof. Harry C. Gatos of Massachusetts Institute of Technology's

Deutsche marque at Indy

Armed with the latest in racing wizardry, Porsche tackles the Brickyard.

Porsche has finally done it. After several years of rumors and conjecture, the tiny German manufacturer has announced it will try to capture the Borg-Warner trophy.

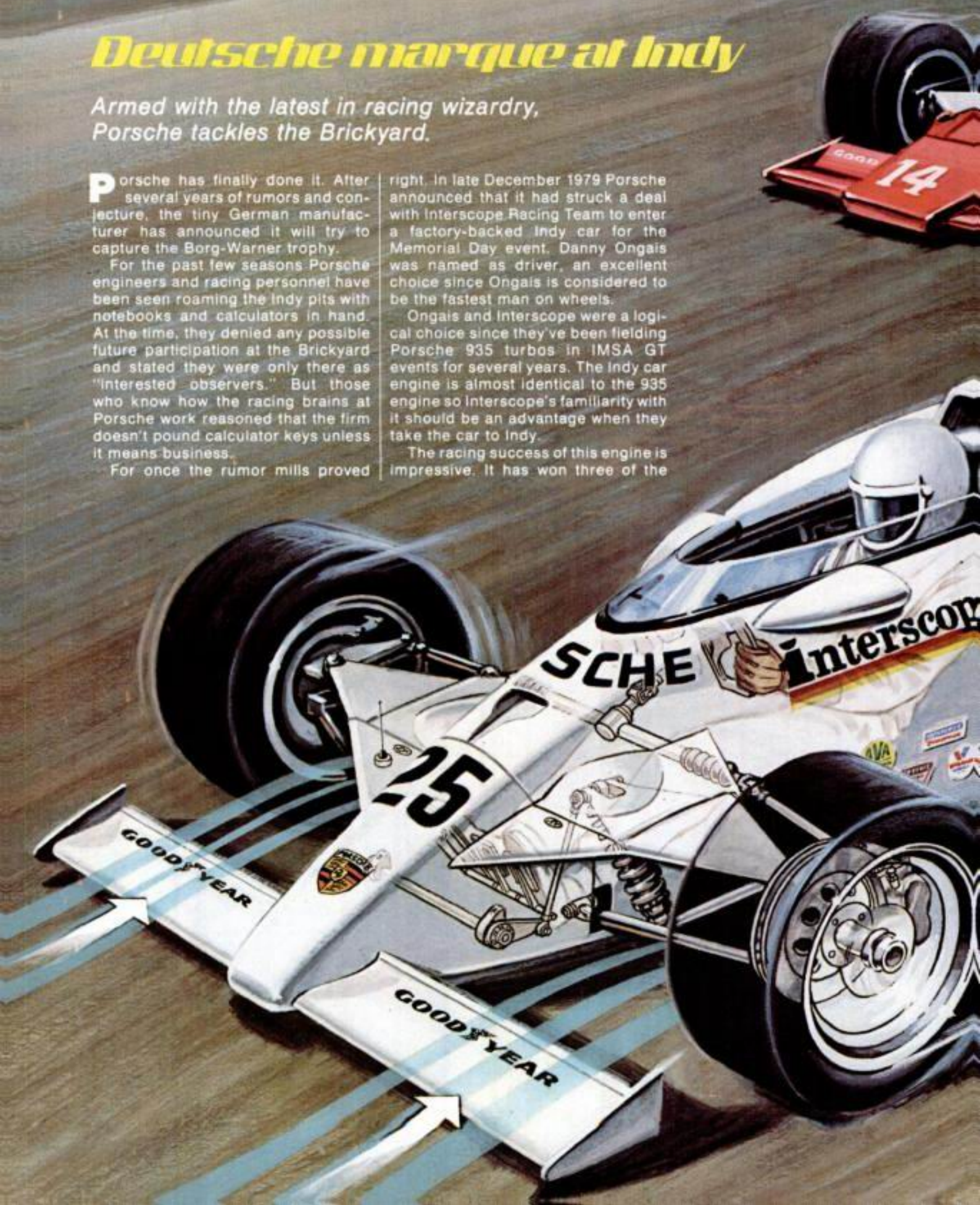
For the past few seasons Porsche engineers and racing personnel have been seen roaming the Indy pits with notebooks and calculators in hand. At the time, they denied any possible future participation at the Brickyard and stated they were only there as "interested observers." But those who know how the racing brains at Porsche work reasoned that the firm doesn't pound calculator keys unless it means business.

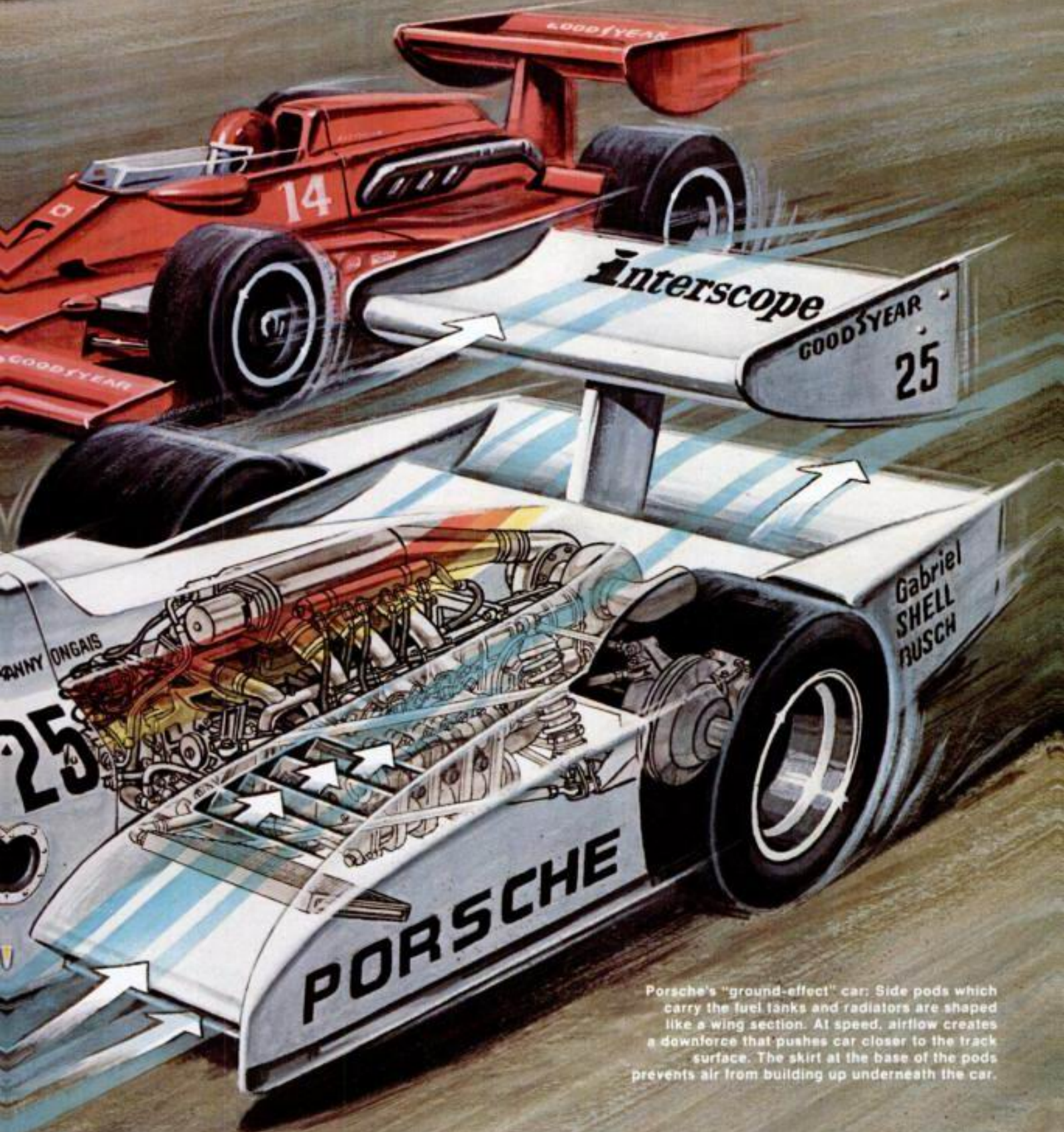
For once the rumor mills proved

right. In late December 1979 Porsche announced that it had struck a deal with Interscope Racing Team to enter a factory-backed Indy car for the Memorial Day event. Danny Ongais was named as driver, an excellent choice since Ongais is considered to be the fastest man on wheels.

Ongais and Interscope were a logical choice since they've been fielding Porsche 935 turbos in IMSA GT events for several years. The Indy car engine is almost identical to the 935 engine so Interscope's familiarity with it should be an advantage when they take the car to Indy.

The racing success of this engine is impressive. It has won three of the





Porsche's "ground-effect" car: Side pods which carry the fuel tanks and radiators are shaped like a wing section. At speed, airflow creates a downforce that pushes car closer to the track surface. The skirt at the base of the pods prevents air from building up underneath the car.

last four Le Mans events and came in first at the Daytona 24-Hours in 1979. If nothing else, the horizontally opposed six-cylinder powerplant has proved to be durable and reliable for endurance events. Porsche feels the engine should have no problems staying together for the 500.

The flat Six displaces 161.7 cu. in. and produces 630 hp at 9000 rpm. It will, of course, be turbocharged and run on methanol.

To keep all that power on the

ground, Porsche has departed radically from conventional Indy chassis design. Borrowing from current Formula 1 technology, Porsche has come up with a "ground-effect" body which essentially uses the entire body of the car as an air-foil. The air rushing over the skin at speed pushes the car to the ground.

Another aerodynamic aid on the Porsche is the skirt, a flexible plastic lip which runs the perimeter of the car and touches the ground.

The combination of ground effect body and skirt work together to produce a vacuum under the car which literally glues it to the surface of the track.

If Porsche's racing history is any indication of success at Indy, it will be an awesome competitor. Armed with the latest state-of-the-art racing technology, Porsche will certainly give the regulars in Gasoline Alley at the Speedway a run for their money.—T.A.

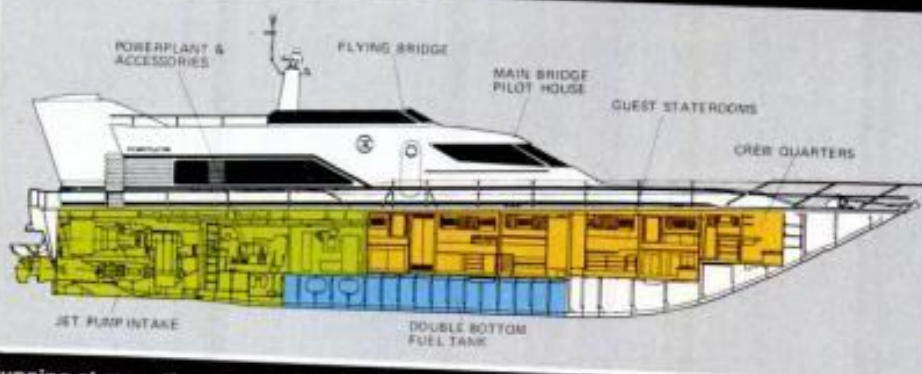
FIRST POWER,

When Crown Prince Fahd of Saudi Arabia decided to make a gift of a new royal yacht to King Juan Carlos of Spain, it was clear that the result would be something extraordinary. The King is an avid boatman and former Olympic sailor, but the possibilities for urgent matters of state suddenly arising in mid-cruise called for a vessel with a little extra turn of speed.

Britain's Don Shead, a naval architect specializing in racing powerboats, designed the King's *Fortuna*. Into an 86-foot hull, Shead inserted ample accommodations for "family cruising" and then went to work in the powerplant department. A combination of two MTU (West German) diesel engines plus an Avco Lycoming gas turbine operating through a 9 to 1 reduction gearbox drives three Rocketdyne water jet pumps—giving *Fortuna* a flat-out speed of over 60 mph and shallow-draft capability (because no propellers protrude) to boot.

Palmer Johnson, a Wisconsin firm specializing in custom yachts, built *Fortuna* using aircraft grade aluminum and the resulting aircraft construction techniques to form the vessel's sleek, deep-V-type hull.

PM

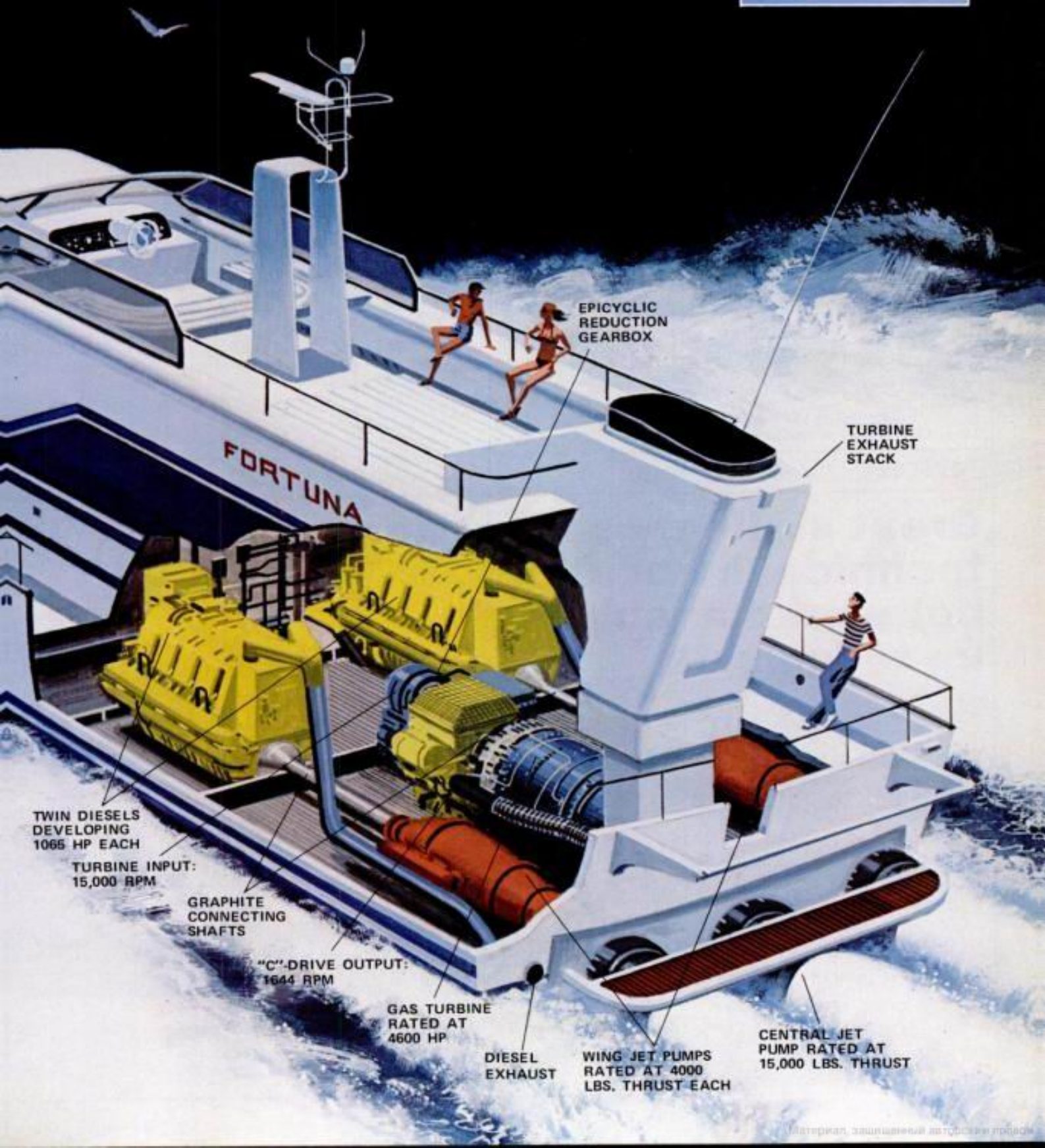


Running at more than 50 mph (photo at top), the *Fortuna*'s turbine/diesel combo powerplant pushes her up over bow wave. Double

bottom aft holds large fuel tanks; interior layout includes owner's stateroom, five cabins, crew quarters, grand salon and galley.

THEN GLORY

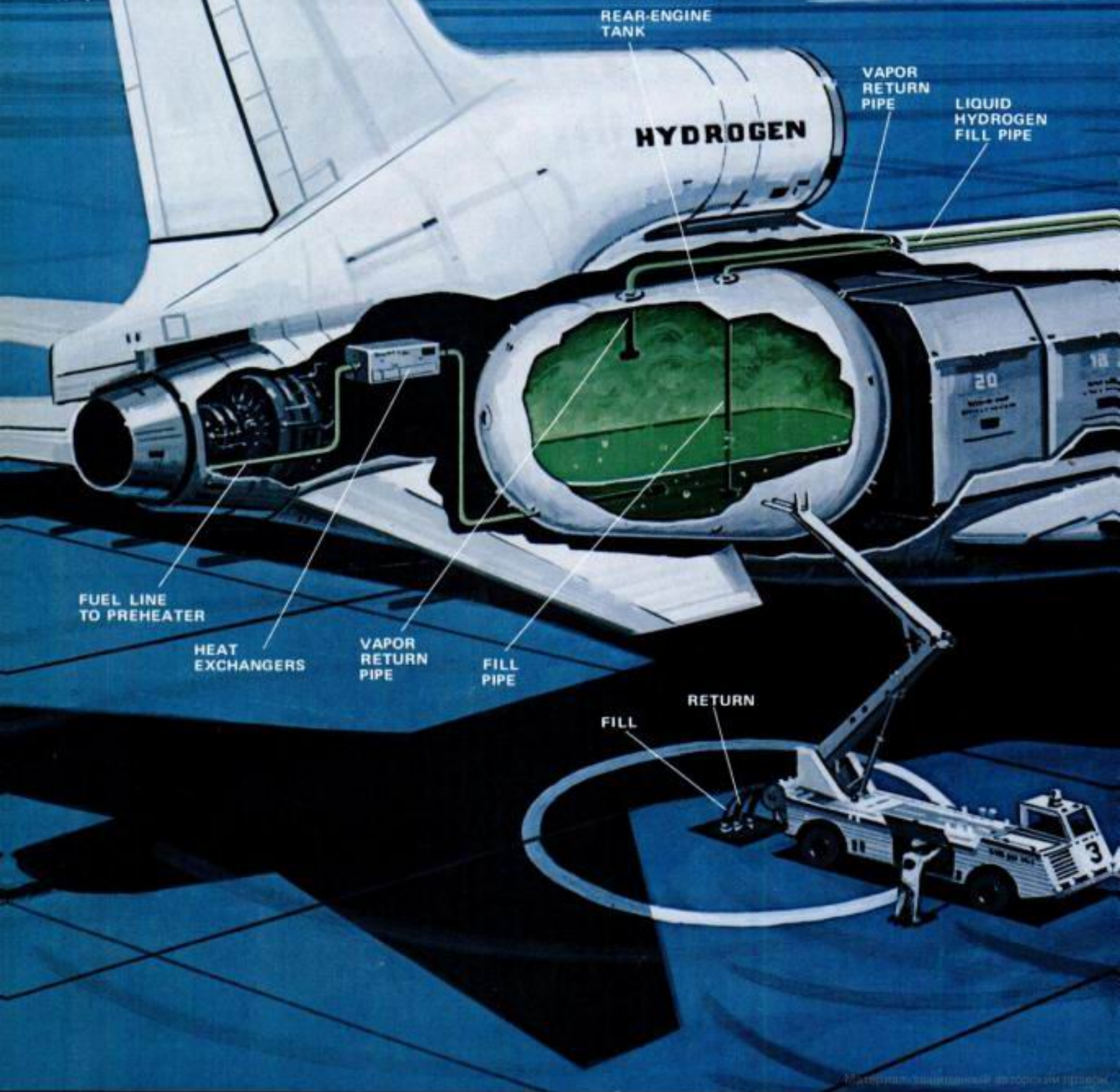
Royal yachts used to be floating palaces, but when the King of Spain wants to truck it on home in this one, he can hit 60 mph.



Hydrogen: new kick for cargo planes

Our strongest ally in fighting OPEC prices might be the lightest element—the best fuel water can provide.

by Tom Johnson



The ground crew scrambles to jam the last few tons of cargo into the bay of the Lockheed L-1011. Gaping doors swallow the final pieces: four skids of machine tools and two limousines, part of a huge but workaday load for the 186-ton plane.

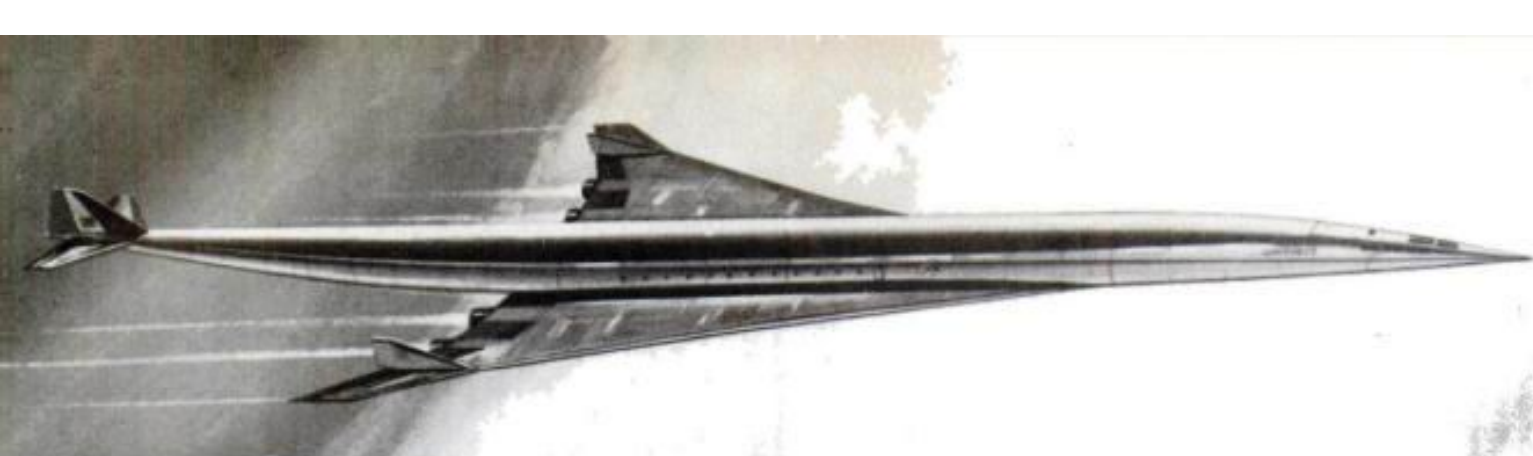
But this is no ordinary plane. For one thing, it is 35 feet longer

than the standard L-1011, to make room for fuel tanks in the fuselage instead of the wings. And in these tanks, feeding the three Rolls-Royce engines as they haul the giant plane toward the sky, is the lightest element on earth, the best fuel water can provide: pollution-free, safe—hydrogen.

A hypothetical account? Yes.

But it's a fantasy moving quickly toward reality. If the efforts of Lockheed, NASA and a half dozen nations prove out, that cargo plane will be lifting off the runway before the end of the decade. Every time the Organization of Petroleum Exporting Countries (OPEC) bumps the price of oil a nickel a barrel, or another explora-





Theoretically, hydrogen-powered passenger plane could carry 234 at cruising speeds around 2000 mph. Range: 4200 miles.

tory well comes up a duster, hydrogen-powered aircraft—to say nothing of cars, home appliances and steel-mill blast furnaces—make more sense as a means to escape petroleum dependence.

It's simple: Hydrogen is light

In many ways, hydrogen is a dream fuel. Raw materials for producing it—natural gas, oil, coal or coal dust, even water—are available around the world. Sensibly handled, hydrogen—especially in liquid form (LH_2)—is safer than most petroleum fuels, except diesel oil.

There are only a couple of "pollutants" resulting from the combustion of hydrogen. One is nitrogen oxide, from burning the nitrogen in air. But this results from burning any jet fuel. The other is water vapor. (A hydrogen-fueled auto engine tested a few years ago emitted exhaust that was cleaner than the air over Chicago streets.)

Best of all, hydrogen releases more heat energy per unit of weight than any other hydrocarbon fuel. Liquid hydrogen is not only lighter

than the top grade of jet-engine fuel (a cubic foot of LH_2 weighs 4.4 pounds compared to 51.6 pounds for jet fuel), but the hydrogen produces 2.8 times more heat (B.T.U.s) per pound. And anything that reduces a plane's fuel load while delivering more thrust per pound of fuel off the runway can set aeronautical engineers like Lockheed's Dan Brewer thinking and tinkering.

"In the early '70s, it was already apparent (that) the peak of crude-oil production in the world would be reached in the mid-1990s," Brewer said in his Lockheed-California office in Burbank. "But before the crisis point is reached, it is imperative for the air-transport industry that development work be completed on a suitable alternate fuel for advanced-design aircraft."

Brewer was not alone in his thinking. NASA began sponsoring research into a variety of fuels to replace that 6 to 10 percent of each barrel of crude oil that is used for high-energy jet fuel. "As a result of these studies," Brewer said, "liquid hydrogen has been shown to be an

outstanding candidate fuel for use in transport aircraft of the future."

Designing that transport of the future—and thinking about the problems of producing, delivering and storing LH_2 at the airports—has been Brewer's assignment for the past eight years. Slowly, other engineers, airline officials and nations joined his dream.

Last fall, 120 representatives from 14 nations meeting in Stuttgart, Germany, enthusiastically agreed to participate in a coordinated research effort to test the practicality of LH_2 aircraft. If, after 30 months of study, the numbers and bench tests fulfill expectations, the plan calls for the startup of an experimental airline.

Airborne by '87?

Aircraft, hydrogen production plants, and storage and fueling facilities at airports would be built for an estimated \$1.3 billion—the cost shared by at least five or six participating nations. Ultimately, a two-to four-plane cargo line flying between cities such as Pittsburgh, Frankfurt, Riyadh, Saudi Arabia, and Birmingham, England would be airborne by 1987 or 1988. (These cities dispatch large quantities of air cargo, and either coal or natural gas is readily available in each to manufacture hydrogen. In fact, much of the natural gas in Saudi Arabia is currently burned off as a waste product.)

Fortunately, most of the nonaircraft technology needed for the project is already known. More than 20 million tons of hydrogen were manufactured and transported by trucks or pipeline in the United States last year. West Germany has nearly 200 miles of pipeline devoted to hydrogen, a fuel generally in wider use in Europe than in North America. Storage systems for liquid hydrogen have been used safely for more than 20 years by the space program.

Major design and development work, however, will fall to the aircraft companies. Lockheed's design

HYDROGEN VS. KEROSENE: WHICH IS SAFER?

POTENTIAL PROBLEM	HOW HYDROGEN WOULD BEHAVE	HOW KEROSENE (COMMON JET FUEL) WOULD BEHAVE
Flammability.	Ignition temperature is high, and if hydrogen ignites it burns rapidly with little radiation and no smoke.	Ignition temperature is low. High radiation, dense and noxious smoke accompany burning.
Human contact with fuel.	Drops of liquid hydrogen turn to gas quickly, causing no damage to human skin. Vapor itself is not toxic. Large amounts of liquid hydrogen have the potential to freeze and destroy tissue.	Kerosene causes little skin irritation. Vapors are toxic.
Contamination from spill.	In air, hydrogen dissipates quickly after vaporizing. Fuel spill would cause no lasting contamination.	Heavier-than-air kerosene would settle toward ground, contaminating area around spill.
Contamination of fuel itself.	Liquid hydrogen does not support growth of organic contaminants because it is stored at low temperatures.	Standard jet fuel is easily contaminated with organic and inorganic substances.
Danger of explosion.	Low, if tank is intact. Stored hydrogen lacks oxygen necessary for detonation.	Kerosene tanks in aircraft contain both fuel and air. Heat can set off explosion.
Temperature increase.	Hydrogen expands with increasing temperature. Pressure from expansion can rupture tanks without adequate venting mechanism. Constant refrigeration or adequate insulation is essential.	Kerosene undergoes little expansion with increasing temperature—a safety plus for conventional fuels.

is the most advanced to date, primarily because it utilizes wing, tail, engine, crew-compartment and landing-gear components already proven on the L-1011 TriStar.

"The fuselage diameter is standard, but the length would be increased about 35 feet to permit fore-and-aft LH₂ fuel tanks," Brewer said. This placement minimizes shifts in the plane's center of gravity as fuel is consumed.

Elimination of conventional wing tanks also cuts down the surface/volume ratio of the fuel-storage tanks, making it easier to keep the fuel at cryogenic temperatures. Liquid hydrogen will be maintained at minus 423° F. by use of a 3- to 3.5-inch insulation sandwich around the tanks with just enough "give" to stand the normal vibrations and stress of flight. If air—typically laden with water vapor—hit a tank wall, frost would build up and the freeze-thaw cycle eventually would crack most insulations. Another novel aspect of the tanks is that they will be an integral part of the airframe instead of the usual separate fuel "containers" to be found in most aircraft.

"Not only will the tank design give more strength with less weight," Brewer said, "but if an insulation crack should develop, it will be easy to spot. Frost will build up on the outside of the plane."

Capitalizing on the cold

Keeping the fuel cold does add some design problems. But Lockheed designers are trying to turn the frigidness of the fuel to their advantage. Cooling the outer skin of the wing, for instance, might smooth the airflow over the wing and fuselage, improving flight performance and saving fuel. Preliminary research indicates that if air passes over an extremely cold surface, it flows much more smoothly.

Lockheed's design calls for using LH₂ to cool an intermediate fluid—gaseous nitrogen seems a likely candidate—which would then be circulated through special channels in the aircraft's surface to reduce the skin temperature to roughly minus 180° F.

Up to now it's just a theory, but engineers estimate that by cooling the engine nacelles, 75 percent of the wing surface and the forward 20 percent of the fuselage, the effect could save as much as 21 percent in direct operating costs because of increased in-flight efficiency.

"Because the cold aircraft skin would freeze water vapor in the air, this system of laminar flow control would only be used above 25,000 to

30,000 feet, where moisture content is not significant," Brewer told the delegates in Stuttgart.

The cold hydrogen will also improve engine efficiency. After the liquid hydrogen leaves the fuel tanks, it will flow through heat exchangers. These enable the fuel itself to take on major cooling jobs—keeping engine-oil temperatures down, for instance—even helping to aircondition the cabin on the ground.

H₂ warms itself

Finally, the hydrogen will pass through a heat exchanger mounted in the engine exhaust. There, the 1800° F. exhaust will bring the fuel up to 761° F. just before it is injected into a combustion chamber, where conventional glow plugs ignite it. Although it will approach the injector at a high temperature, the hydrogen will remain a liquid up to that point because it will be under high pressure—750 pounds per square inch (p.s.i.). Because the hydrogen is heated, it will vaporize faster for a

greater combustion efficiency.

The heat-transfer units will fit easily into the pod of the Rolls-Royce RB 211-22B engines with minor modifications. "All four of these heat exchangers on each engine will only weigh 240 pounds," Brewer said, "and their use will reduce fuel consumption by about 8 percent."

The energy advantages, while impressive, are only part of the savings anticipated by the designers of hydrogen-powered aircraft. For one thing, the comparatively low weight of the fuel reduces the overall weight of the plane. And that in turn cuts construction costs, by about 3 percent. And as traditional petroleum fuel prices escalate, the cost advantage of LH₂ will increase as well, Brewer believes. He would not be surprised, he told PM, if the per-mile cost of a hydrogen-powered plane with laminar flow cooling is half that of conventional jets by the end of the decade.

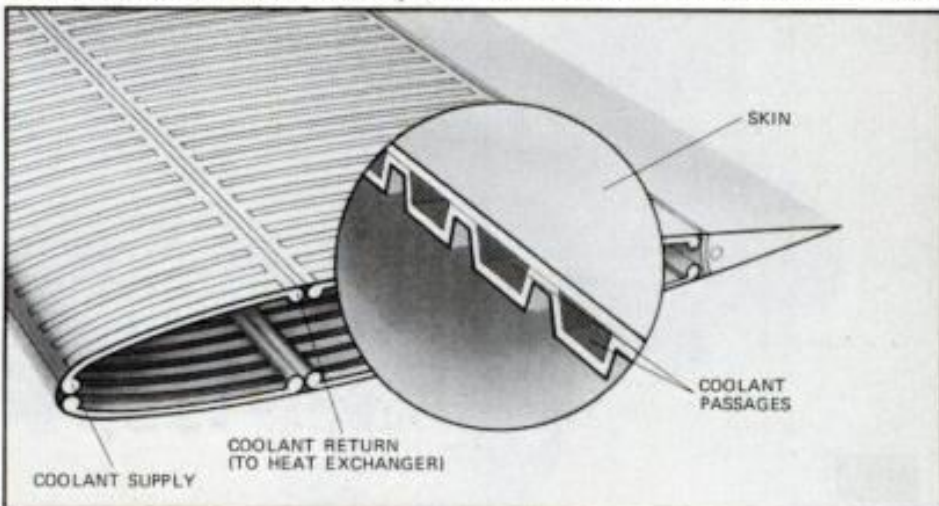
Researchers outside of Lockheed are inclined to agree that hydrogen

(Please turn to page 244)



Four-engine subsonic hydrogen plane could carry 400 passengers seated on two decks.

Lockheed design calls for cooling the wing surfaces at high altitude to improve air-flow and cut friction. Liquid hydrogen fuel would chill coolant, probably nitrogen.



TECH FRONT LINES

The 1984 airship: Roomy, slow, easy to land—and cheap

The stately dirigible, once a symbol of pokey but luxurious air travel, is coming back as a cargo-hauling workhorse.

If Britain's Redcoat Cargo Airlines follows through on its plans, a new breed of \$10 million airships will begin plying trade routes between the United Kingdom and West Africa in 1984. These craft will travel at a slow—and economical—68 knots. At the same time, U.S. designers are penciling huge ovals on their drawing boards, planning a role for dirigibles as giant cranes in the sky.

And one American company, Federal Express, has held preliminary talks with Airship about buying dirigibles to deliver packages in the late '80s.

The incentive is potential savings. With much of the lift provided by helium, airships may cut fuel costs by roughly a third.

It wasn't just the promise of higher profits that attracted Redcoat, a gutsy, 4-year-old company that hauls heavy machinery, racing horses, oil pipes, chemicals, baby chicks and other freight in turboprop planes (motto: "Redcoats are coming"). A couple of years ago, company directors decided the days of fixed-wing, cargo-hauling aircraft were numbered. Rising costs, they calculated, would ground the fleet in a few years. So they turned to another British firm, Airship Industries Ltd., which had been promoting lighter-than-air vehicles for a decade. During that period, it had corralled much of the world's airship-design talent.

Some of Airship's proposed aircraft resemble flying saucers—

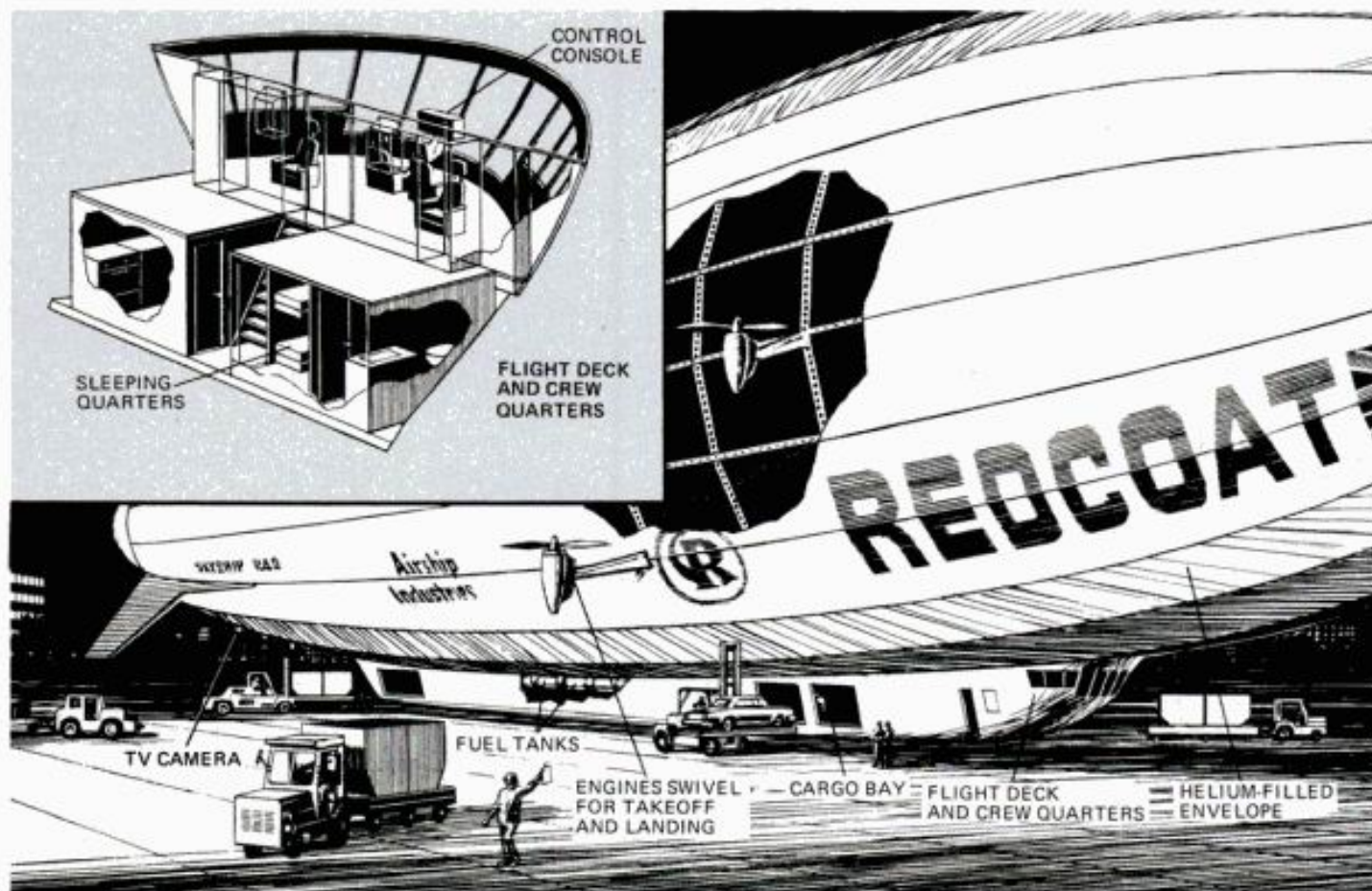
pillow-shaped ships with circular passenger quarters and engines thrusting out at each quadrant.

The firm is also in the process of completing several nonrigid "blimps" for offshore fisheries' surveillance. The first of these will fly in 1981. "The latter is an especially safe and sensible solution," says Malcolm Wren, chairman of Airship Industries, "when you consider that the U.S. Navy safely operated 160 airships in World War II for more than 20 million miles, with the

AVIATION

only casualty coming from enemy action."

The rigid, metal-framed "R-150" airships ordered by Redcoat look more like traditional dirigibles. But the current models have capabilities that make the hydrogen-filled giants of the '30s look as antiquated as dinosaurs. "The old airships were notoriously underpowered and lacking in maneuverability," says Airship



Industries' chief designer, Patrick Monk. "A 1930s engine was unreliable and weighed perhaps three pounds per horsepower produced, whereas our turbines weigh only $\frac{3}{10}$ pound per horsepower. Finally, we now know a lot more about aerodynamic design. We'll have a stronger, lighter, ship using new materials, such as Kevlar, and we'll carry state-of-the-art communications gear and weather radar."

Each of the new airships will contain some 4.5 million cubic feet of helium, and carry 40 tons of cargo 2,500 miles, or up to 58 tons for shorter distances. Powered by four turboprop engines, the 600-foot-long ship (200 feet shorter than Germany's *Hindenburg*) will reach West African destinations in about 2½ days.

Although slow in comparison to jet aircraft, the airships will reduce the typical ocean-going freighter's shipping time by more than 50 percent. And, in this hare-and-tortoise competition, the lumbering airships wind up beating jets in some respects. "The proposed R-150 airship should allow us to carry

U.K. exports overseas for at least 29 percent less cost than on narrow-bodied jet aircraft," says Kevin McPhillips, a founding partner of Redcoat. "And while it's true that a wide-body jumbo jet, such as the 747, can lift more weight than the R-150—all well and good for shipping something dense and heavy—our airship will have a cargo hold volume of nearly 38,000 cu. ft. That's 56 percent more space than the 747."

And unlike the 747—and dirigibles of the 1930s—the R-150 ought to be able to land almost anywhere. The turbine engines can be fully swiveled up or down, to allow vertical takeoff and landing. Engines on earlier dirigibles were fixed in position, necessitating a larger operating area. Redcoat's airships will be able to move cargo directly inland, close to customers' facilities.

Giant weightlifter

Engineers in the United States agree that airships still have a place in the sky. Goodyear Aerospace Corp., for one, is doing a good deal more than lofting blimps over baseball stadiums. The Akron, Ohio, airship designer is working on nonrigid coastal patrol airships for the Naval Air Development Center. The company is exploring basic airship design in partnership with the National Aeronautics and Space Administration. And it's promoting an idea for a heavy-lift airship—a true flying crane—capable of transporting 75 tons. Helicopter rotors would supplement the lifting power of helium.

Goodyear has some competition on this crane idea from a small Philadelphia company, Piasecki Aircraft Corp. The firm has won a government contract to build an airship capable of lifting 26 tons and carting it 1,500 miles. The 340-foot-long dirigible is a hybrid, like Goodyear's weightlifter. Four Sikorsky H-34 helicopters are connected by an aluminum frame to the helium-filled envelope.

Only one of the helicopters—the one to the left and rear of the envelope—contains the crew, a pilot and copilot. The other choppers are drones, linked to the command ship. They maneuver the ship over the cargo after it



Piasecki's hybrid: new log lifter.



Airship envelope nears completion.

cruises to the site at about 65 knots.

This extraordinary airship, approaching completion at the Lakehurst, N.J. Naval Air Engineering Center, is slated for action in the Pacific northwest.

Again, the promise of substantial savings is keeping the airship idea aloft. Road-building costs for logging operations are approaching \$150,000 per mile. So the U.S. Forest Service is open to new—even old—ideas. Piasecki's \$10.5-million "Heli-Stat" is expected to cut almost 40 percent off the cost of aerial timber harvesting as currently done by helicopter.

Company officials tell PM that their weightlifter ought to be able to handle assignments hauling materials to construction sites or lowering bridge components into place. It could also compensate for a growing problem at ports around the world: There aren't enough cranes to load and unload cargo.

Shortly, the latest hybrid airship, buoyed by an inert, harmless, lightweight gas, may become a heavy-duty stevedore at major ports around the world.



better. Looking at the Polaroid SX-70 or the new Sun Camera, one feature that stands out is the round, golden-grilled object just above or next to the lens. This device, called a transducer, is the heart of Polaroid's sonar-based, autofocus system.

The transducer can be considered a very accurate, four-toned speaker. Inside it, very thin, plastic film vibrates as voltage is applied and sends out tones of 60, 57, 53 and 50 kHz.

The sound waves bounce back to the transducer from objects they strike between about an inch and 35 feet away. The detected echoes are processed digitally, then the lens of the camera is adjusted to focus through analog circuitry.

In use, the system was fail-safe. The SX-70 camera requires you to first depress the shutter partway in order to focus. The Sun Camera allows for focusing and shooting in one movement, though it sacrifices

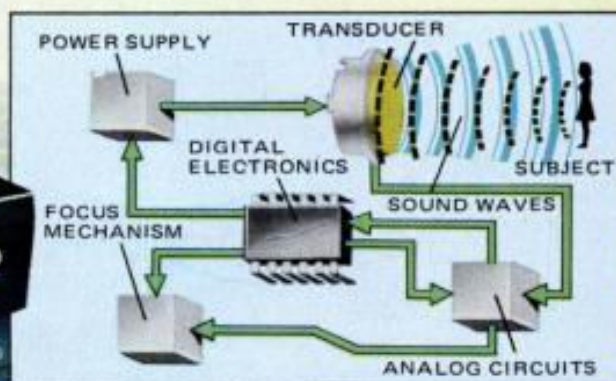
the SX-70's close-up abilities.

Every shot we took was in focus. Of course, there are certain shooting conditions to avoid. Obviously, you cannot focus automatically from behind a window, since the camera will focus on the window pane. Likewise, complex surfaces, such as leafy plants, could fool it.

But for everyday shooting, it couples the surety of autofocus with the quick gratification of develop-while-you-wait Polaroid film.

POLAROID SX-70

POLAROID SUN 660



Polaroid system of sonar-ranging (detailed above) uses a transducer next to lens. The transducer sends out sound waves, echoes of which are processed by computerized (digital) and normal (analog) circuits. The Canon AL-1 (left) uses charge-coupled devices to autofocus. Incoming light is split into three beams. Each hits a CCD and the camera's on-board microprocessor interprets results and suggests focus.



CANON AL-1

TRANSMITTIVE MIRROR

BEAM SPLITTER

CHARGE-COUPLED DEVICES (CCD)

PM art: Jeff Mangiat

Split to focus

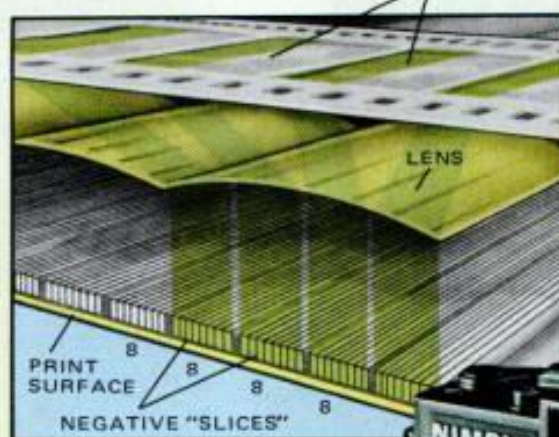
Canon's new system of autofocus departs dramatically from the sonar style. The Canon AL-1 is loaded with leading-edge, electronic technology in the form of three charge-coupled device (CCD) integrated circuits.

When you first pick up the camera and look into its ground-glass viewfinder, nothing seems unusual. But when you begin to focus on something and press the shutter lightly, the magic begins.

As an object comes into focus, three tiny indicators in the viewfinder guide you to focusing perfection. A left- or right-pointing, red

(Please turn to page 185)

HALF-SIZE NEGATIVES



Nimslo 3D's four lenses use half-size negatives. Each carries scene from different viewpoint. Negatives are sliced and arranged beneath lenses which cover print. Lenses blend image for 3-D. The Kodak Disc 8000 has new disc film, autoadvance, autoflash and great depth of field. Sony Mavica uses no film; it stores picture electronically in Mavipak.

KODAK DISC 8000

CARTRIDGE FRONT
SEPARATOR LAYER



LENSES

NIMSLO 3D

CARTRIDGE BACK

NEGATIVE DISC

MAVIPAK

HOME TV

MAVICA VIEWER



SONY MAVICA

VIDEO CIRCUIT

CHARGE-COUPLED DEVICE (CCD)

New Cameras That Make Photography Easy

Cameras that autofocus, others that take 3-D pictures or some that use no conventional film at all make picture taking more fun than ever.

by Neil Shapiro ELECTRONICS EDITOR

For shutterbugs or camera buffs, there are new systems that put the thrill back into taking pictures. It's easier than ever to click the shutter for a fine photo to show off later. We checked out six cameras, using these new systems, and were impressed by the fine results and startling designs.

The Polaroid sonar-imaging system for automatic focusing is an integral part of the SX-70 and new Sun Camera we used. Kodak's new disc system makes the Disc 8000 camera a treat. A new method of electronic autofocus turns the Canon AL-1 into a 35-mm friend. The three-dimensional effect of the Nimslo is astonishing. And Sony's plans for the Mavica system of no-film photography sound grand.

Times have never been

Polaroid Sun 660



Polaroid SX-70



Canon AL-1



Nimslo 3D



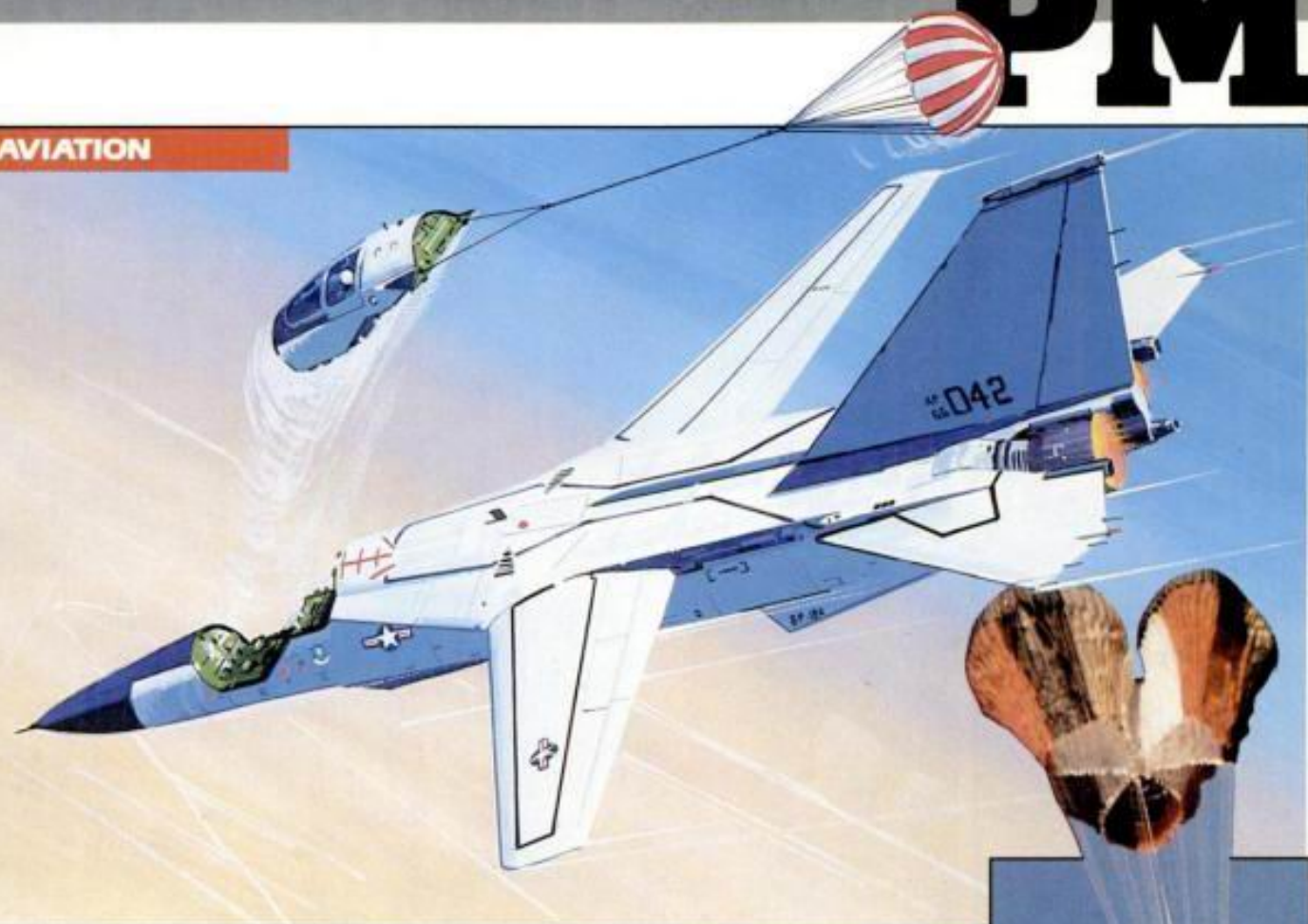
Sony Mavica

Handsome-looking cameras above help you take great shots. The Polaroids (Sun 660 and SX-70) have a sonar-ranging autofocus system. Canon AL-1 uses new, integrated-circuit technology for its autofocus. The Nimslo 3D takes three-dimensional photos on specially processed film. Kodak's disc system potentially puts easy-to-use cameras in everyone's grasp. In the meantime, Sony is trying to turn photography around with the Mavica all-electronic, filmless camera.



Kodak Disc 8000

AVIATION



New Chute System For F-111 Egress Pod

Developments in electronic warfare have added nearly 300 pounds to the Air Force's workhorse F-111, which means the plane's cockpit escape module (illustrated) must now descend by parachute at 35 ft. per second after an emergency punch out. The Air Force recently decided to reduce

the module's descent rate to a safer 25 ft. per second and asked Sandia National Laboratory to design a replacement for the F-111's single 70-ft. ringsail parachute. The result (pictured) is a cluster of three 52.5-ft.-dia. parachutes that rely on conventional ripstop Nylon and Kevlar in structural and sus-

pension lines. Each parachute weighs only 30 pounds and develops a drag force of 8000 pounds.

The new parachutes were recently attached to test vehicles (right) carrying on-board accelerometers, load-measuring instruments, cameras, cinetheodolites and tracking telescopes.



Light Weight, High Strength

The Pontiac Motorsports Division is testing a magnesium-based, inline, 4-cylinder engine block that is approximately 100 pounds lighter than its cast-iron equivalent. A typical "Magblock" is sand cast using ZE41 magnesium and weighs a scant 41.9 pounds. Compare that to the 116.7-pound weight of a conventional block of similar displacement. The engine was developed for off-road/motorsports applications.



F-15 Electronic Enhancements

The new and improved McDonnell Douglas F-15E will undertake deep interdiction fighter/bomber missions, relying on conformal fuel tanks for extra range and an updated electronics package. Items include the Hughes APG-70 radar, Martin-Marietta Low Altitude Navigation and Targeting Infrared

(LANTIRN) system and inertial navigation by Honeywell that incorporates the revolutionary laser ring gyro. The F-15E also has a second cockpit for a weapons system/countermeasures operator. The Air Force plans to add 392 F-15Es to the existing fleet of twin-engine supersonic F-15s.

TECHNOLOGY UPDATE 4/86

ROBOTICS

Robot truck takes steps

The Defense Department funded it, but by the next decade, Ohio State University researchers hope their Adaptive Suspension Vehicle will find more peaceful uses. The 17-ft. ASV moves on six legs at speeds near 8 mph. Experiments are under way in which a prototype machine is being programmed to scale 7-ft. walls and cross 9-ft. ditches. It is powered by a 70-hp 900-cc motorcycle engine. Researchers are looking for other ideas. Submit yours to Tech Update, Popular Mechanics, 224 West 57th St., New York, NY 10019.



A robotic squadron

Remotely Piloted Vehicles (RPVs) have been used by the Israeli army to locate artillery targets and take pictures behind enemy lines. Now the American Defense Department is developing RPVs that may be used in formation like a reconnaissance wing. The Lockheed Aquila RPV (right) takes off on a pneumatic rail launcher, then flies on a 2-cylinder piston engine. It has a 12.7-ft. wingspan, weighs about 200 pounds with its cameras installed and hardly shows up on radar. A future mission for an advanced turbofan-powered RPV wing might be



to penetrate a nuclear battlefield and take pictures of damage or embattlements. No manned craft currently in the fleet could penetrate a nuclear battlefield and fly low enough to take useful spy photos.



MILITARY

Unmanned tank killer

British Aerospace's new antitank off-route mine puts out a laser pulse that can sense the presence of a tank at 150 yards. If a tank crosses the path of the tripod-mounted weapon, an AT4 antitank projectile is fired



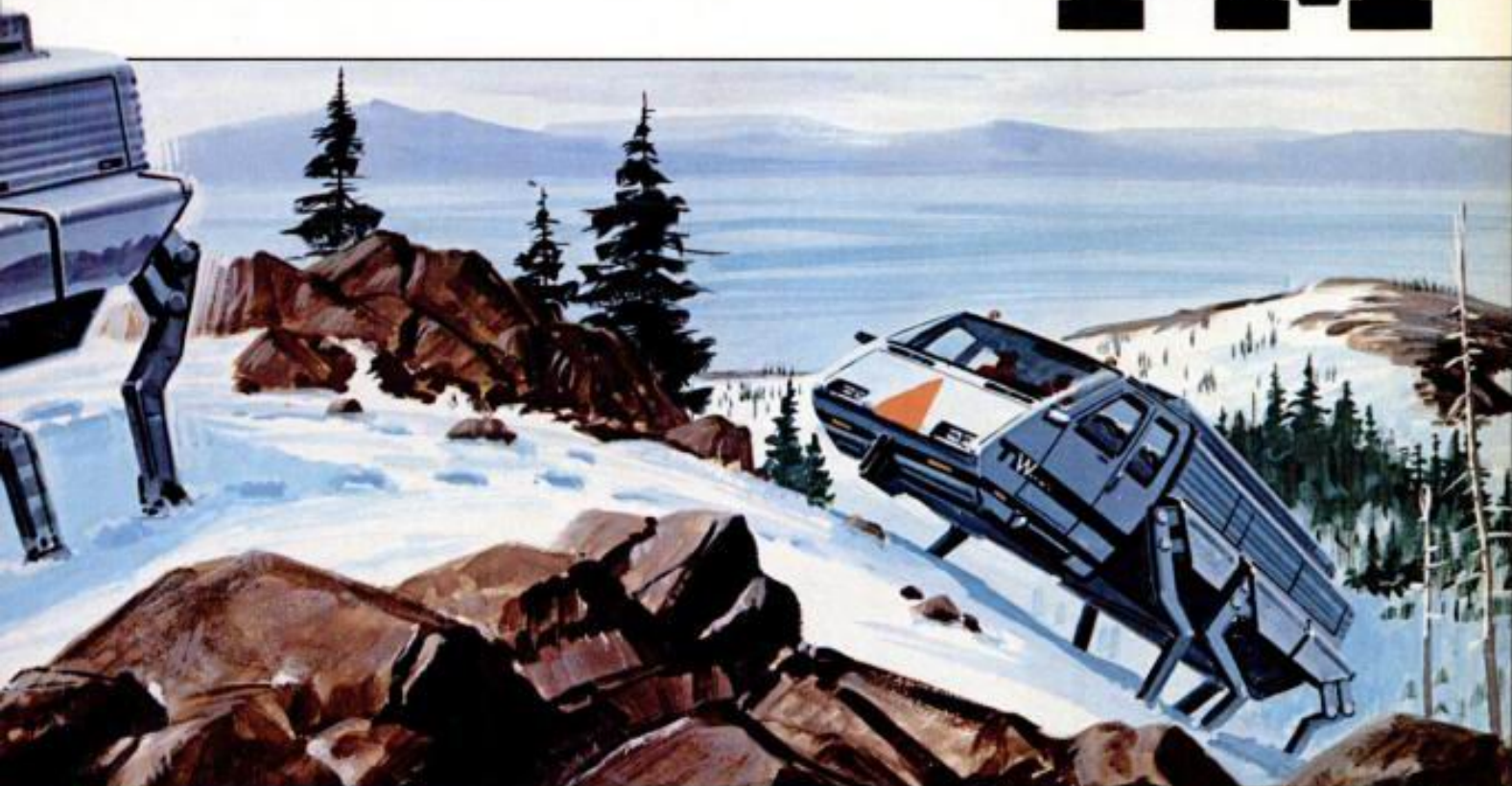
automatically. The Defense Department is evaluating the off-route mine.

The Penguin strikes again

The villain in the Batman comics specialized in knocking over banks. But this Penguin is a new fire-and-forget missile from Norway. Shown

under the wing of a Norwegian F-16, the Penguin will be used as an antisubmarine weapon in an area where Soviet subs run rampant.





MARINE

New vessel explores lake

Michigan State University scientists are using the 2-man submersible Johnson Sea-Link II to conduct the first studies of the bottom of a large freshwater body. Timothy Wilson and David Long are shown 1319 ft. below Lake Superior in preliminary dives last summer.

Among other things, they discovered freshwater cod (below) at the lake's deepest points. This summer, the scientists will conduct in-depth research on the lake's life and structure.



The swift and the strong

Sweden's Weedo Batar boat works has introduced a prototype 14-man rescue boat that runs through icy waters at 40 knots on a jet engine. The 1-ton graphite hull has

passed capsize-resistant tests in Sweden and England. The Swedish Coast Guard will begin trial runs with the boat next winter. Trials in England are under way now.



LASERS

Laser fits like a glove

Uniphase has announced the most compact laser, a helium-neon model that takes highly accurate readings of

chemically treated surfaces. Small grocery and dry goods stores can now use the same laser coding available to mass marketers. It will be available from Edmund Scientific this summer. It's also useful for amateur experimenters.



Windclipper prototype, based on a modified Kenworth chassis, features high-mounted driver's cab rigidly attached to the trailer. Power/tractor unit pivots below the cab. Controls run through fifth wheel.



TRUCKIN' INTO THE FUTURE

Slick new trucks are already on the road,
but the best are yet to come.

Among truckers, there may still be scoffers who think aerodynamic shapes like droop hoods and air deflectors are too dainty to fit the image of a tough, powerful road machine. But if the experience of car designers is any clue, the scoffers will dwindle in number as the tally of wind-cheating shapes in the big haulers' fleets continues to grow.

The automobile companies' first efforts at aerodynamic car bodies were criticized as "the melted candy bar look." But now, aerodynamic bodies are fully accepted as the normal way to construct a sedan.

That's what insiders look for in the truck designs of the future—cabs that not only make sense in saving fuel costs, but that appear completely different from the traditional broad-shouldered, level hoods of most current models. The changes have already started.



BY JIM DUNNE, Detroit Editor

Trucks from a number of the bigger makers—especially White, Kenworth, Peterbilt and Freightliner—are primarily designed to slide through the air at 55 mph with the least amount of resistance. At the same time they lose little of the macho style that truckers seem to prefer in their rigs.

The benefits of the new designs are more than just big money savings from improved fuel economy. New designs will also deliver:

- Lower noise levels inside the cabs and outside on the road.
- Much more room inside the cabs of the taller trucks.
- Better handling, especially when heavy winds buffet the semis from the side.
- Better forward visibility over hood and fenders.

In addition, if the truck and trailer panels are shaped carefully, brakes and tires will run cooler, operate more efficiently and probably last longer than those on today's models.

The switch to aerodynamics in trucks has been going on for just about 10 years, and today it's a rare semi tractor that is sold without at least a rooftop airshield. Many of the truck owners are choosing more elaborate aero systems, those that add side extenders and integral sleepers to cab contours designed in the wind tunnel.

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BATTLECRUISER 2000

In the coming century, a lethal combination of stealth and firepower will revolutionize warfare on the high seas.

BY NICK NICHOLS; PM Illustrations by Tom Freeman

"No profession is more wedded to the folklore of the past than the armed services."—Winston Churchill

THAT esteemed son of Britannia might have added that none of the armed services is more heavily shackled to tradition than the U.S. Navy. Who else in this age of high-tech mania would have recommissioned that venerable emissary of "gunboat diplomacy," the *USS New Jersey*?

Touting a different diplomacy, recently retired Vice Adm. Joseph Metcalf III told PM, "Institutions die hard, and the U.S. Navy is a very mature bureaucracy." Not that he isn't an advocate of putting more ordnance to sea, far from it—it's the type of ordnance that Metcalf's concerned with. The admiral feels that recent technological advancements in weaponry and command, control and communications (C³) systems have yielded an opportunity to completely reevaluate "the way we do business," from surface ship design and construction to strategy and tactics.

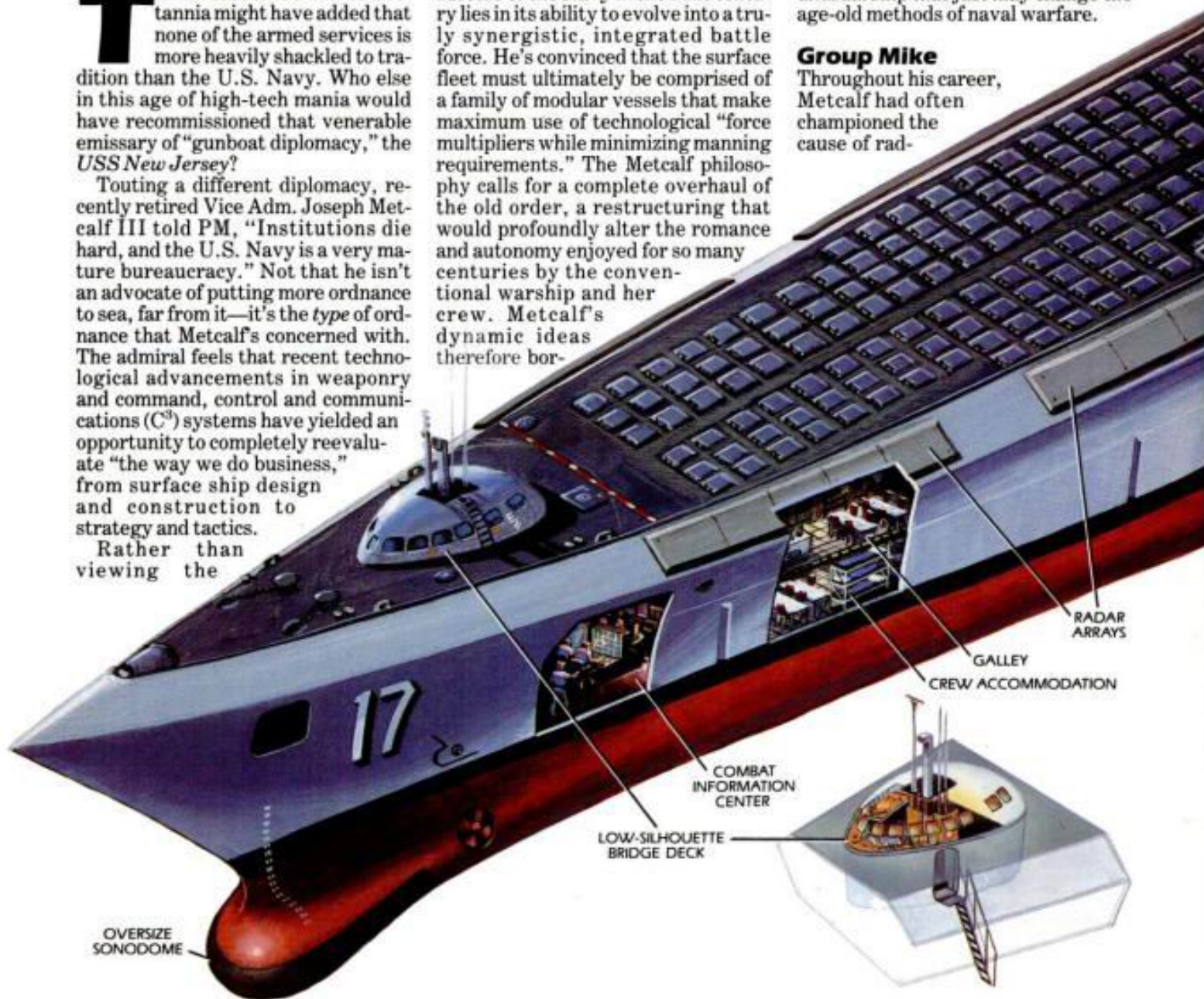
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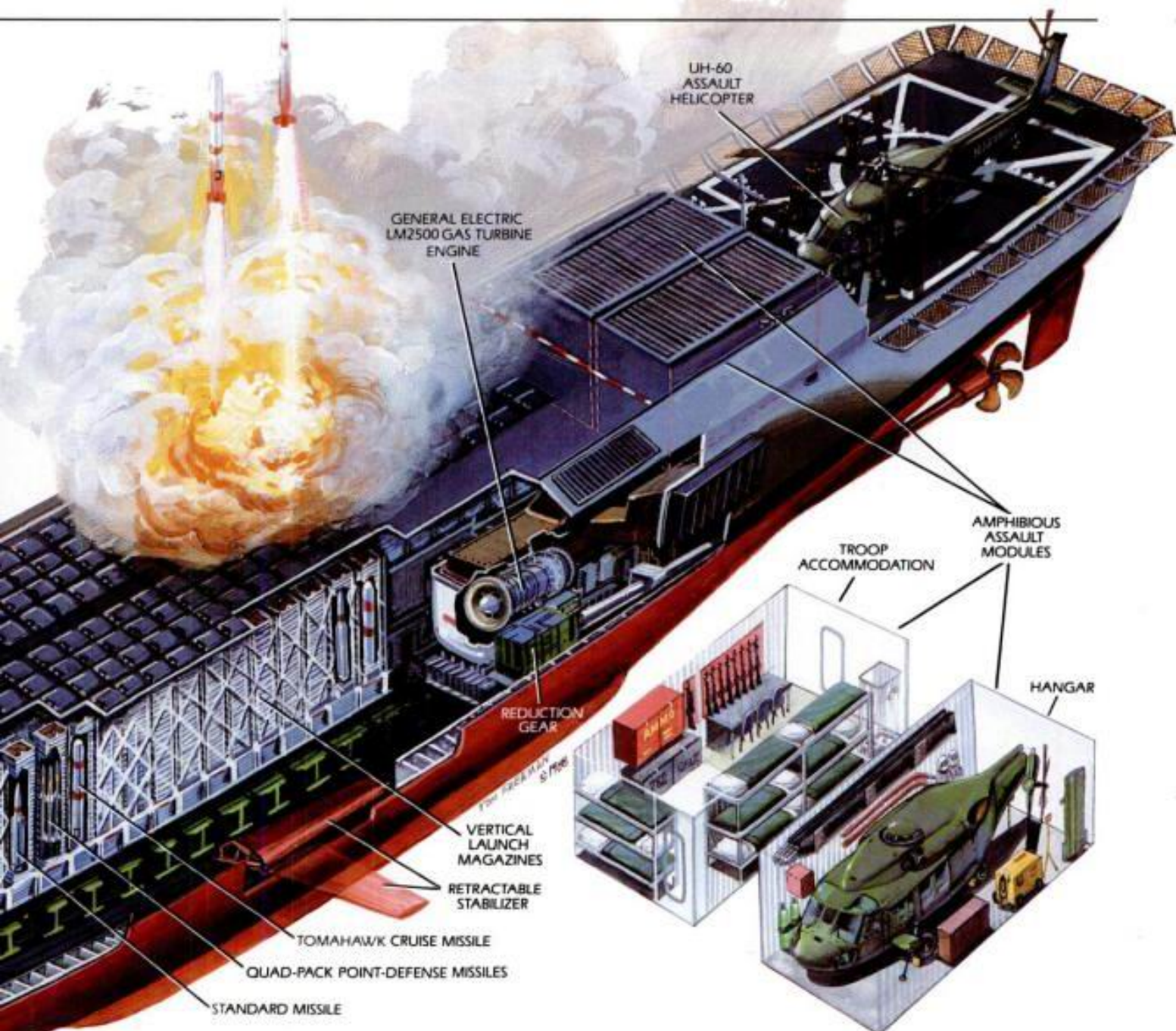
surface fleet as a collection of self-contained, floating arsenals (as typified by today's martial leviathan, the aircraft carrier), Metcalf believes the success of the Navy in the next century lies in its ability to evolve into a truly synergistic, integrated battle force. He's convinced that the surface fleet must ultimately be comprised of a family of modular vessels that make maximum use of technological "force multipliers while minimizing manning requirements." The Metcalf philosophy calls for a complete overhaul of the old order, a restructuring that would profoundly alter the romance and autonomy enjoyed for so many centuries by the conventional warship and her crew. Metcalf's dynamic ideas therefore bor-

der on heresy in the eyes of hidebound traditionalists. In short, the maverick mariner is instigating a revolution! And the focus of this revolution is an unusual ship that just may change the age-old methods of naval warfare.

Group Mike

Throughout his career, Metcalf had often championed the cause of rad-





ical departure from orthodox doctrine, and in his influential preretirement job as Deputy Chief of Naval Operations for Surface Warfare, he finally found himself in a position to do something about it.

The project that took shape in late 1986 under Metcalf's guiding hand was aptly christened the Revolution at Sea initiative, and a supervisory work/study group was established to oversee the various phases of the broad-based research effort. Fiercely loyal to their progressive leader, this body of officers adopted the phonetic-M title of "Group Mike" in recognition of Metcalf's personal commitment to the project.

Group Mike's innovative ship is the physical manifestation of Metcalf's preoccupation with "putting maximum ordnance on target." More im-

portantly, the admiral sees his visionary vessel as the heir-apparent to the primary strike role currently filled by the aircraft carrier.

"We're almost to the point where we're going to be able to eliminate manned aircraft from the naval scenario altogether," explains Metcalf. "Before long, both offensive and defensive duties in the fleet are going to be handled by missiles of various types."

For example, the offensive task of deep interdiction—presently the exclusive turf of carrier-based aviators—can be more efficiently fulfilled by precision-guided, long-range cruise missiles, according to Metcalf.

The admiral hints that antiaircraft/antimissile laser weapons will soon be numbered among the ship's defensive armament.

Conceived as a means to get more ordnance on target more accurately, the stealth ship of tomorrow will carry multiple magazines of vertical launch missiles. Perfected on baseline-two ships of the Aegis cruiser series, the vertical launch system brings a variety of smart missiles to bear on different targets in a complex battle environment. The future variant of the Tomahawk cruise missile will strike land targets more than 1350 miles away. Updated Standard surface-to-air missiles will defend the ship and her battle group from air and missile threats. Antisubmarine rockets (ASROCs) will knock out submarines. Salvos of smaller missiles will help defend the ship. Marked by a low silhouette, supersensing radar arrays, and carrying remotely piloted surveillance aircraft, the ship of tomorrow will also incorporate mission-specific modules in the stern to accommodate amphibious assault teams, SEAL units or even X-wing fighters.

WEEKEND WORKSHOP: EASY-TO-BUILD KITCHEN CART N 6

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TECH UPDATE

News Of Tomorrow's Technology Today



First Scramjet Could Piggyback On Blackbird

EDWARDS AFB, CA—Remember the X-15? The rocket-powered plane shattered all-time speed records as it blazed the trail for vehicles like the Space Shuttle.

Now NASA's Ames-Dryden Flight Research Facility has blueprinted a '90s version of the X-15, to pave the way for the X-30, the National Aero-Space Plane. HALO (High-Altitude Launch Option) is a 58-ft. rocket-boosted vehicle to be launched from an SR-71 Blackbird.

HALO's rockets would propel the aircraft to a speed of Mach 12 and an altitude of 145,000 ft. Then the plane would turn on its scramjet (the supersonic-combustion powerplant destined for the

X-30). HALO would test the engine for 2 minutes and glide back to Edwards.

Data from HALO flights, say Dryden engineers, could mesh with data from tests of SAPHYRE, a classified unmanned Mach-25 rocket vehicle developed at Sandia National Labs. The two vehicles could explore the high and low speeds of the X-30's flight regime separately.

How would HALO/SAPHYRE square with the X-30, itself an exploratory aircraft? The question is stirring debate, especially since budget cuts have stretched out the X-30's gen-

esis. Meanwhile, engineers plan wind-tunnel model tests for the HALO/Blackbird tandem this spring.

HALO scramjet testbed rockets away from SR-71, on its way to Mach-12 speeds in stratospheric proving ground.

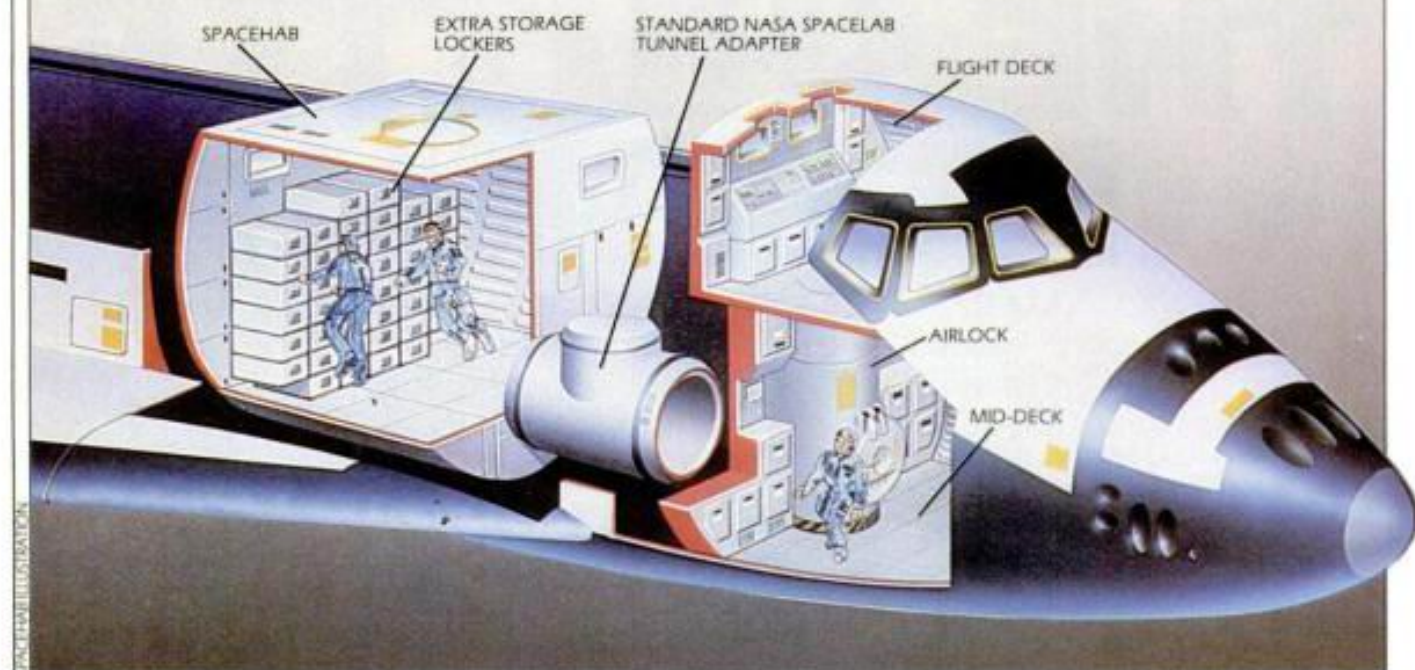
Highlights This Month

- **Shoot The Moon**—NASA spells out long-layover lunar mission.
- **To Explore New Worlds**—Telescope array will search for alien planets.
- **Sell It To The Marines**—Rival amphibious vehicles square off.
- **World's Smartest Dummy**—Robotic mannequin models protective uniforms.
- **No Resistance**—Superconducting power lines are here.
- **Trial Balloon**—Star Wars missile watchers get lighter than air.

Editor: Abe Dane
Assistant Editor: Greg Pope
Contributor: Mike Fillon

THE SHUTTLE REBORN

Expanding Shuttle Capabilities



Extending Shuttle's future usefulness, a Spacehab payload insert will allow the vehicle to carry more crew and science experiments.

third O-ring, pressure-actuated flap and leak-test ports were ultimately added to the case-to-nozzle joint. Lastly, Stat-O-Seal washers were added to the radial bolts in the joint to further prevent gas leaks.

In mid-April, the third full-scale test took place using a deliberately flawed engine. Designated Qualifying Motor-6 (QM-6), engineers put a wave defect in the surface of the bonded insulation J-seal. This defect allowed hot gases to penetrate the bonded insulation as far as the capture feature O-ring. Results of the test showed that there was no leaking gas, and the wave defect self-sealed, as designed.

The SRM design that will fly on STS-26, is the same as was successfully tested on Development Motor-8 (DM-8). NASA had high hopes for a more advanced SRM design, which it tested on Development Motor-9. However, after the DM-9 qualification test, inspections discovered material missing from a 140° sector of the outer carbon phenolic ring that anchors a protective boot over the nozzle swiveling joint. Later on, one-third of the material was found inside the motor.

This now infamous part is known as the outer boot ring, a 2-in.-thick sealing washer that protects a flexible bearing that allows the nozzle to swivel and steer the rocket. The test involved slewing the nozzle 7°, the maximum possible angle. During a normal Shuttle ascent, the nozzle

would normally slew only 0.5 to 2.0 degrees. However, to be on the safe side, NASA dropped the DM-9 design for the *Discovery* flight.

During the QM-6 test, the nozzle was swung up to 6.3° without a problem. More than 500 instruments were fitted to the motor to measure acceleration, pressure, deflection, thrust, strain and other conditions.

As of press time, two more tests were being planned in June that would test still further the performance of an SRM with extreme flaws.

Main engine rehab

While work has proceeded on the solid-rocket motors, the Shuttle's main engines (SSME) have also undergone a metamorphosis. Improvements have been made in the electronic engine controller, valve actuators, temperature sensors and turbopumps.

In the high-pressure turbomachinery, turbine blades and bearings have undergone changes for added durability. Engineers have applied surface texture to some parts of the fuel turbine blades to improve performance under hydrogen fuel pressure.

In addition, the main combustion chamber has been made more durable by nickel-plating a welded outlet manifold. Improvements have also been made to the five hydraulic actuators to prevent a loss in redundancy. A temperature sensor, which failed on an earlier flight, has been redesigned

and tested without problems. However, the SSMEs have not escaped their own problems. One of the engines originally scheduled to fly on STS-26, developed a leak in its oxidizer heat exchanger. At the time, officials said the leak was minor, but the engine was pulled from the flight. Defective welds were also discovered on seals in the high-pressure fuel turbopumps at the turbine inlet.

There were problems with the high-pressure liquid-oxygen pumps. After ground tests, vibration caused loosening and the tightening of small screws that hold a retainer ring, which secures a honeycomb seal at the turbine blade. The screws are torqued and staked in with a center-punch. If the 0.25-in. screws are not installed properly, the ring could break apart. After an inspection, the problem does not appear to affect STS-26 engines. "So we have pumps on now that we feel good about," says an MSFC spokesperson.

According to Cmdr. Hauck, the orbiter itself has undergone some significant changes. "We have redone some of the electronic circuitry that controls the auxiliary power units. We have modified some of the tile in the chin area—the area right under the orbiter nose cone. We have beefed-up the payload bay structure and also added new heat-sink material there."

There is also a new emergency egress system that uses a 241-pound aluminum and steel telescoping pole.

Shuttle Propulsion Advancements



NASA engineers have used Shuttle downtime to improve engine components.

The design was chosen over a tractor-rocket extraction system after experiments with both systems earlier this year. The system is designed for emergencies during controlled gliding flight either on ascent or reentry. But Hauck notes that, "it wouldn't help in a *Challenger*-type explosion."

Other changes on *Discovery* include reinforced wings, heftier tires, stronger axles and brakes, and improved nose-wheel steering.

Is there concern about *Discovery* having been grounded so long? "No," says Launch Director Bob Seeke.

"Even in late 1986 when there was not much work on it, we still had requirements to do, which included inspections. And we have periodically activated systems because of the concern over having the orbiter sit and not fly. Like putting a car on blocks, the smart thing to do is periodically start the engine and pump the brakes." He adds, "Once we started the modifications and the testing over a year ago, there has been extensive work done on *Discovery*. So it has never been totally dormant."

Yes, America's Space Shuttle has changed. No longer will it fly with many of the engineering flaws it previously had. No longer will it deliver commercial satellites. No longer will it land at its Florida launch site—or California's Vandenberg Air Force Base. And, no longer will it be our only access to space. Expendable launchers will be lofting reconnaissance and communications satellites. But the Space Shuttle does remain our only link to the Space Station, to future lunar bases and quite possibly to Mars. When *Discovery* goes into orbit, America's hopes for a future in space go with it.

PM



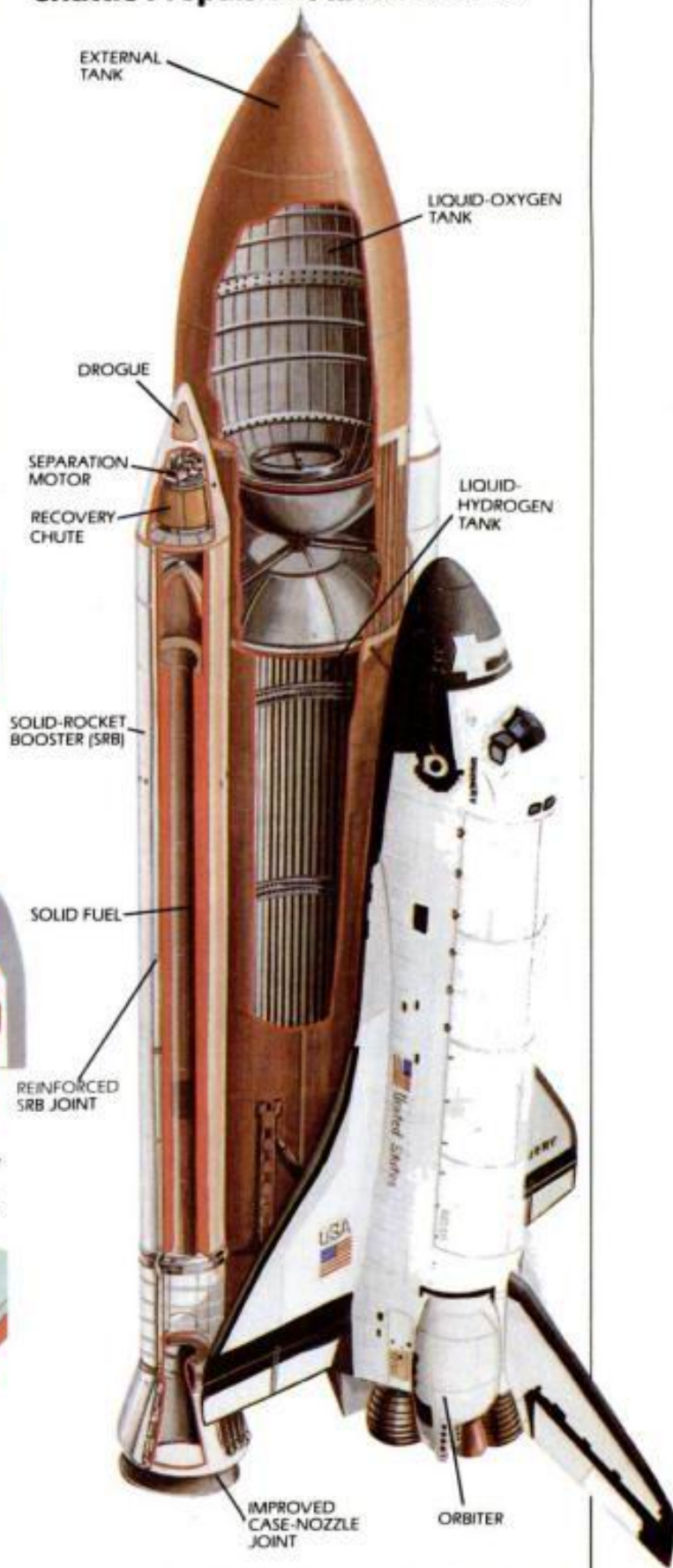
Challenger's offending SRB joint was a simple tang-and-clevis design.



More O-rings, a heater and a weather seal have been added to new groove-in-groove design.



Special washer seals have also been added to bolts in the booster's case-to-nozzle joint.



A key to America's space hopes, the Space Shuttle keeps its basic propulsion design. But NASA says improvements in the solid-rocket booster and in the orbiter's main engines will make the system more reliable.

AMERICA'S OIL TANKER MESS

back most of those 240,000 barrels."

Thus, Prince William Sound became an environmental Pearl Harbor. The damage was staggering, with cleanup costs likely to exceed \$1 billion, a \$150-million-a-year fishing industry threatened, and an enduring stain left on a part of the world that residents justly think of as God's country. Secretary of Transportation Samuel K. Skinner declared the spill to be "one of the worst environmental and economic disasters this nation has ever faced."

As if to drive the message home, three smaller but still serious spills occurred exactly three months after the *Valdez* accident. In one extraordinary weekend, spills of between 250,000 and 420,000 gallons each fouled the waters of Rhode Island, Delaware and Texas.

So far, investigations have laid responsibility for all of the accidents to mistakes by crewmen. But they have also raised disturbing questions about equipment and procedures.

Six parts oil, one part steel

Modern tankers are uniquely fragile and unwieldy vessels. According to Lincoln Crane, chief of the Stability and Control Division of the Davidson Laboratory at the Stevens Institute of Technology, the idea in tanker design is "to get as much cargo as you can into as little steel as possible, and still have economical propulsion." The larger the ship, the simpler this task is to accomplish. As a result, over the past three decades the largest tankers have grown from vessels of no more than 121,000 tons into quarter-mile-long behemoths displacing 640,000 tons, and drawing up to 90 ft.

ULCCs, or Ultra Large Crude Car-

riers as these ships are called, require 3 miles and 20 minutes to stop from a top speed of 15 to 16 knots. To make matters worse, the low ratio of steel to cargo—1:6 in the case of the *Exxon Valdez*—makes them vulnerable to rupture at the gentlest brush with an unyielding object.

The double-hull controversy

Of the safety measures now being considered, none has inspired more heated debate than a proposed requirement that a second layer of steel



First of three in a weekend, the *World Prodigy* spill coated the shores of Rhode Island.

be laid inside a ship's framework, resulting in either a double bottom or double hull (see illustrations opposite). Hardly an untried idea, twin skins of one kind or another are present on virtually all of the 60,000 merchant ships afloat—except for oil tankers.

Double hulls are already required on tankers carrying hazardous cargoes such as liquefied natural gas, and more than once have been credited with preventing disaster.

On July 1, 1979, the LNG tanker *El Paso Paul Keyser* steamed onto a rock ledge in the Strait of Gibraltar at a speed of 17 to 18 knots. Although the outer hull was torn open under four of



the six cargo tanks, the inner hull suffered only a minor dent, and none of the 95,000 cubic meters of highly volatile cargo escaped.

Experiences such as this are backed up by several studies. A 1975 Coast Guard analysis of 30 oil-tanker groundings concluded that double bottoms with a 2-meter separation between the layers would have prevented spills 96 percent of the time. Studies by Congress's Office of Technology Assessment, the National Transportation Safety Board and others provided supporting evidence.

In the wake of the 1976 wreck of the *Argo Merchant*, which introduced 7.6 million gallons of oil into the waters off Nantucket, President Carter proposed that double bottoms be required on all tankers over 20,000-tons dead weight (the weight of the ship's cargo alone). The measure was rejected, however, by a convention of maritime nations, and replaced by one calling for segregated ballast tanks (see illustration above). Set aside strictly for seawater ballast, carried to stabilize the ship when it is empty of oil, these tanks are placed so as to provide some protection against collision.

Justifying the move, the oil and shipping industries offered two basic objections to twin skins. First, they said, oil could leak into the void space between the inner and outer plating, forming a vapor that could explode. But, according to Arthur MacKenzie, who was on the OTA panel that studied tanker safety in the 1970s and now runs a casualty reporting service called the Tanker Advisory Center, there has not been one explosion attributed to a double hull or double bottom in the past 25 years, although some 530 tankers have them.

The industry also claimed that if the outer layer of a twin-skinned tanker were breached, water filling the void space could cause the ship to lose buoyancy and come harder aground, increasing the difficulty of salvage and possibly causing it to capsize.

OIL TANKER PROFILES



EASTERN SUN—Length: 641 ft. Capacity: 30,252 tons.



TEXAS SUN—Length: 752 ft. Capacity: 50,864 tons.



MEDITERRANEAN SUN—Length: 889 ft. Capacity: 134,835 tons.



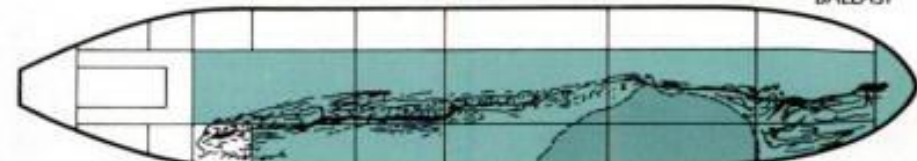
ATLANTIC SUN—Length: 1117 ft. Capacity: 255,850 tons.



ESSO ATLANTIC—Length: 1200 ft. Capacity: 508,731 tons.

INSIDE A MODERN SUPERTANKER

Built in 1986, the ill-fated *Exxon Valdez* incorporated five protectively located, segregated ballast tanks. Placed in likely collision zones, these satisfy the latest safety regulations, but did nothing to prevent massive leakage when the ship ran aground.



Initial grounding left a gash running from the *Valdez's* forepeak to her starboard slop tank. The 11 colored tanks were all holed. Darkened area was caved in when she came to rest.

Capt. Warren Leback, a member of the Marine Board of the National Academy of Engineering who supervised the salvage of the *El Paso Paul Keyser*, disagrees. "With double bottoms and wing ballast tanks, you're actually in a better position to start a salvage operation," he says, reasoning that having the vessel firmly aground at first makes it easier to work on. Then, when the vessel is ready to be floated, the compartments between the inner and outer hulls provide a space to blow compressed air into, without offloading.

Capt. J.H. Boyd, Navy Supervisor of Salvage from 1973 to 1976, puts it more succinctly. "I view the probability of a major salvage or pollution incident growing out of the grounding of a large single-bottom tanker an order of magnitude greater than that for a double-bottom tanker."

In April of this year, Sen. Brock Adams (D-Wash.) began a new attempt to require double plating. A version of his bill, approved in August, will require the Coast Guard to either produce regulations mandating the safeguard, or explain why it is not needed.

Charting the future

Of course, if ships could be prevented from running into things, there would be no need to armor them against impact. Over the past 10 years, devices have evolved that could make the taxing business of navigating a large ship less chancy.

Among the most promising are systems known as electronic charts. These take the data from the navigational equipment already aboard most vessels, including loran, global positioning satellite receivers, depth sounders, radar and gyrocompasses, and integrate them with a computer database of digitized nautical charts.

The result is a single video readout that shows the ship's location and course with respect to the shoreline, bottom contours, buoys, markers and other ships. "It's a very, very powerful display," says Morton Rogoff, head of the Radio Technical Commission for Maritime Services.

Acknowledged to be the most thoroughly developed system of this kind, is one called the Precise Integrated Navigation System made by Offshore Systems of Vancouver. With the aid of radar reflectors placed on shore, the system is able to determine the ship's location to within 1 to 2 meters.

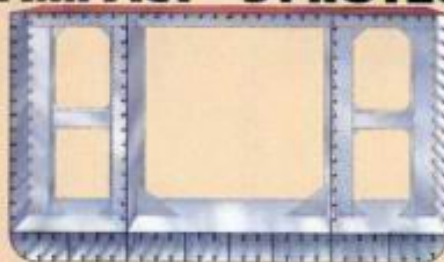
Now in use aboard a handful of Ca-

BRACING FOR IMPACT—3 PROTECTION LEVELS



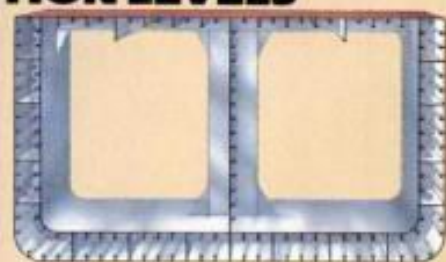
SINGLE SKIN

Light, cheap and traditional, this design prevails despite longer tanker hulls.



DOUBLE BOTTOM

Inner bottom adds strength, and contains oil if grounding breaches outer bottom.

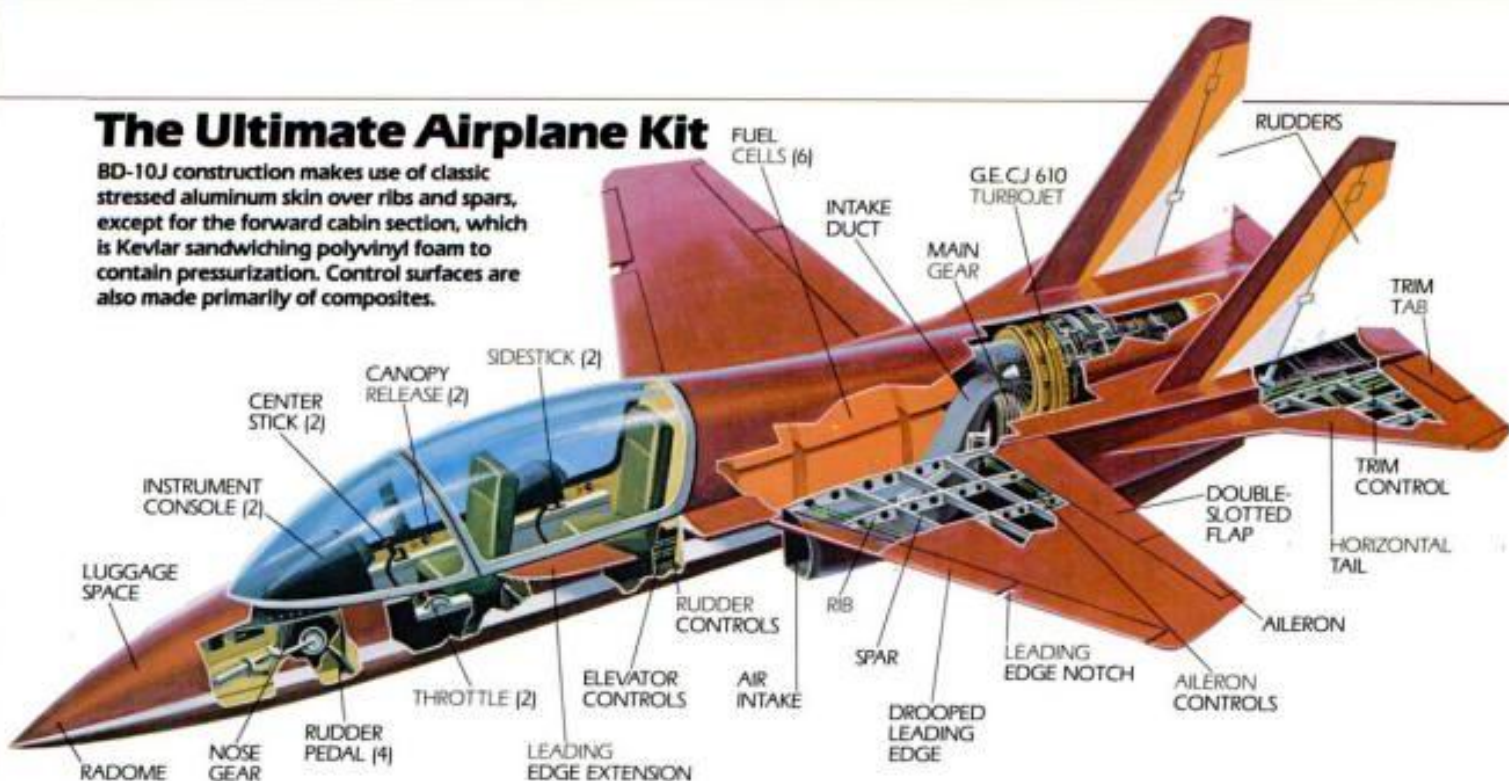


DOUBLE HULL

Required on hazardous chemical carriers, wraparound void space protects in crash.

The Ultimate Airplane Kit

BD-10J construction makes use of classic stressed aluminum skin over ribs and spars, except for the forward cabin section, which is Kevlar sandwiching polyvinyl foam to contain pressurization. Control surfaces are also made primarily of composites.



The BD-10J's 35-pounds-per-sq.-ft. wing loading drops to 18 pounds per sq. ft. with low fuel loads typical just prior to landing. That gives the aircraft a 70-mph stall, which results in an approach speed of about 90 mph. Landing distances of 1500 to 2000 ft. are anticipated, however, since the CJ 610 will continue to produce about 140 pounds of thrust when pulled back to idle.

There is no pilot ejection system. But if customer interest is strong enough, Bede might offer a powered parachute that would pull the pilot out, if the need arose. The aircraft is equipped with a fuel dump system, thus minimizing the risk of fire in a dead stick, emergency landing.

Building underway

Construction of the first four preproduction versions of the plane is now taking place at Bede's Oklahoma City shop. Original plans to build a prototype were scrapped, because it was felt that only a plane built on production tooling would represent the final version's characteristics accurately enough for certification trials.

Bede expects the first BD-10J to be finished sometime in February, after which flight testing will begin in Mojave. National Airshows Group, operator of the Holiday Inn Aerobatic team will do the flying, and will also be among Bede's first customers.

Bidding for that privilege has apparently been brisk. Bede says he already has 18 firm orders, which may take him nearly a year to fill. He won't even begin accepting new orders until this summer. As for the four preproduction planes now under construction, Bede won't say who's getting

them, except that serial No. 1 is reserved for himself.

National Airshows Group will also handle customer training. Bede says that in the beginning all prospective customers will be expected to come to the manufacturing site and fly with a factory instructor in a BD-10J and demonstrate enough proficiency to handle the aircraft safely. The BD-10J, says Bede, "is just too much aircraft to simply turn over to someone who happens to have a lot of money and the ability to buy it."

The BD-10J will probably be sold only as a complete kit, minus engine and avionics. Initially, Bede had intended to sell plans for the plane to anyone interested. However, as the project took shape, he decided that that idea was unrealistic. "The airplane is too complicated for a guy to even try building it from scratch," Bede says. Instead, the factory will produce all composite components in vacuum ovens and will be responsible for all complicated formed or machined parts.

The aircraft fall into FAA's homebuilt Experimental certification category. Bede does not intend to manufacture complete BD-10Js, at least not for the civil market.

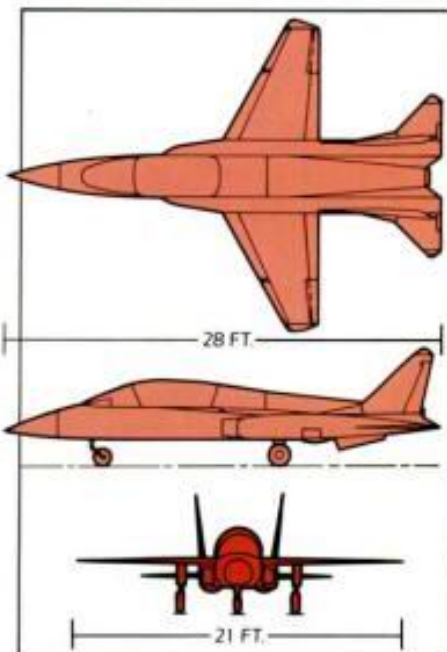
Waiting in the wings

When Bede began his jet project, his intent was to produce the hottest airplane ever to hit the air-show circuit. The market wasn't a big one. He estimated 15 airplanes would do it. However, as word of the BD-10J spread, letters and calls began to overwhelm the little Advanced Aircraft office. Bede says he has received some 1100 inquiries about his minifighter.

And what about the air-show performers for whom it was originally targeted?

Bob Bishop is a one-time Bede Aircraft test pilot who now makes his living in a BD-5 as the leader of the Coors Light Silver Bullets aerobatic team. He thinks the BD-10J concept is a bold one and, supersonic practicalities aside, that the aircraft "will be neat no matter what it does."

But beyond that, if the BD-10J delivers all that Bede promises, Bishop believes the aircraft "could change the face of aviation." That is an observation that may be echoed again and again once the BD-10J takes flight. **PM**



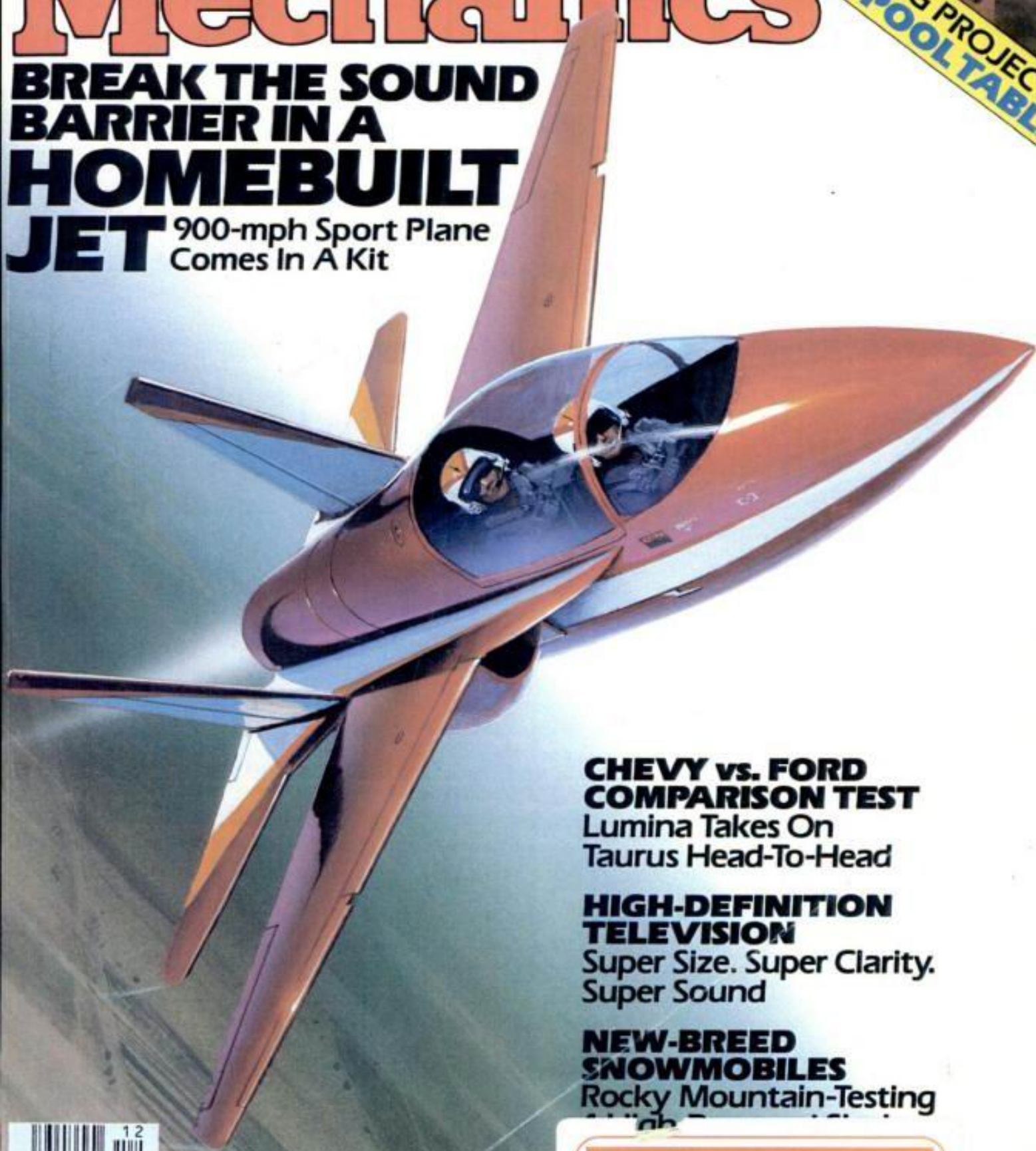
Twin vertical, and fully movable horizontal tails betray BD-10Js' fighter heritage, but light wing loading allows for manageable landing speeds.

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SCIENCE

Giant Gyros

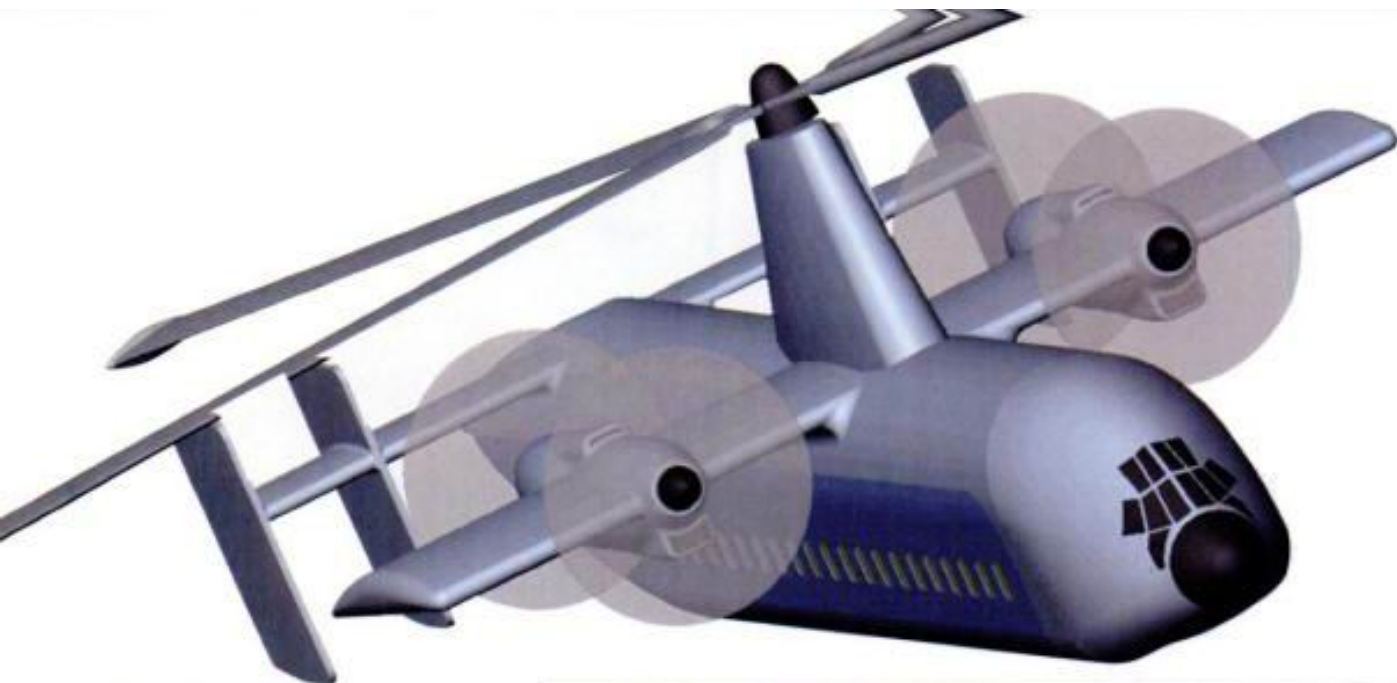
Heavy-lift gyroplanes haul civilization to the far corners of the world.

BY **JIM WILSON** ILLUSTRATION BY **PAUL DIMARE**





Some of the world's most valuable resources are in the last places on Earth. The wastelands of Siberia, the rain forests of Brazil and the deserts of Antarctica hold vast stores of rare metals, oil and natural gas. Despite their value, these treasures remain untouched. It is simply too expensive to bring in the manpower and equipment needed to extract them. Over the next decade, this situation will change as a new fleet of fast, powerful and versatile aircraft—heavy-lift gyroplanes—take to the sky.



Winged aircraft can carry massive loads. The Ukrainian-built Antonov An-225, for example, can transport more than 500,000 pounds. Helicopters have a limited lifting capability compared to cargo planes. The tradeoff is their ability to operate without a runway. Gyroplanes offer the perfect compromise between lifting capability and versatility. Although many have proposed gyroplanes, only two companies remain active: Groen Bros. Aviation (GBA) of Salt Lake City, Utah, and Carter Aviation Technologies of Wichita Falls, Texas. Here is what they have on their drawing boards.

GBA GYROLIFTER

"More than 40 years ago Fairey Aviation Co., a British aircraft manufacturer, developed a revolutionary new type of aircraft called the Rotodyne," says company founder David Groen. "It used rotorblade tip-jets to power its rotor for vertical takeoff and landing." The jets were shut down in flight, and conventionally mounted propeller engines carried the 44-passenger aircraft at 200 mph.

Although technically successful, the Rotodyne never fired the imagination of airline executives and the plane was abandoned. "If the Fairey Rotodyne existed today, even without modern improvements, it would still be the fastest, safest method of travel," says Groen. "GBA has developed a plan that can rapidly bring the Rotodyne into the modern age."

GROEN GYROLIFTER



Rotor Diameter	112 ft.
Max Payload	40,000 lb.
Range At Max Payload	863 miles
Cruise Speed	288 mph



"Although many have proposed gyroplanes, only two companies remain active."

Groen's idea is to create "runway independent aircraft" by incorporating rotor components into existing production airplanes. He has identified about a half-dozen existing commercial aircraft suitable for conversion. "It would be relatively easy and inexpensive to transform the Lockheed Martin C-130 cargo transport into a heavy-lift GyroLifter by equipping it with a GBA-designed rotor system incorporating rotor-mounted tip-jets," says Groen. "The technology is simple and the engineering risks are low."

GBA has successfully tested the concept using a modified Cessna

Skymaster, a 6-place aircraft with an unusual fore-and-aft engine configuration. The Cessna's forward engine was replaced with a Rolls-Royce gas turbine. Its rear engine was replaced with a large cargo door. Existing wings were shortened, and the twin-boom tail was inverted to create rotor clearance. A rotor assembly from an existing GBA Hawk 4 Gyroplane was connected to the wing attach points already carrying the fuselage. The ungainly aircraft took to the air like a duck to water. "It demonstrated the characteristics of a well-designed gyroplane," Groen says.

In addition to operating in remote locations, the GyroLifter, Groen believes, could help the United States deal with runway overcrowding by turning almost any patch of ground into a commercial airport.

CARTER HELIPLANE

"The CarterCopter Heliplane is comparable in payload and flight performance to the C-130J Hercules," says



CARTER HELIPLANE



Rotor Diameter	150 ft.
Max Payload	45,000 lb.
Range At Max Payload	1500 miles
Cruise Speed	420 mph



company founder Jay Carter. "It takes off, hovers and lands like a helicopter." In forward flight the rotor slows and a long, thin wing provides lift.

Where Groen uses tip-jets to provide the energy needed for vertical flight, Carter uses 900 pounds of tip-mounted

weight. Before takeoff, the rotor is accelerated to 128 rpm. "The tip weights store energy like a flywheel," Carter explains. "The extra horsepower that this inertial-boost provides permits the Heliplane to reach its minimum steady flight speed by the

time the rotor rpm has dropped to its normal speed." As the Heliplane's forward speed increases, the rotor slows. At 400 mph the rotor is turning at 25 rpm and creating less than 20 percent of the aircraft's lift. "The Heliplane is now flying essentially as a fixed-wing aircraft," says Carter.

Last year, Carter Aviation locked up a series of patents covering various aspects of the Heliplane's design and operation. The company also has begun work on a three-tenths scale Heliplane Transport, which it will use for safety and reliability testing.

FUTURE HEAVY LIFTERS

Within the aircraft industry, there is talk of larger and faster cargo carriers. Ultralight, high-strength composites will make it possible to construct multiple-rotor machines capable of lifting a million pounds.

Until recently, it was believed that the speed of a rotorcraft was limited by the so-called Mu (μ) barrier. Mu is the ratio of the forward speed of an aircraft to the tip speed of the rotor. At ratios of Mu-1 rotorcraft become highly unstable. "We know that to maintain a Mu of 0.75 the rotor pitch can't vary much more than 1 degree," says Carter. He believes that advanced automation systems will eventually solve this problem. Cracking the Mu barrier will open the door to heavy-lift gyroplanes that approach supersonic speeds. **PM**

HEAVY-LIFT ROTORCRAFT

HELICOPTERS



■ **BOEING CHINOOK**
Payload: 28,000 lb.



■ **SIKORSKY SUPER STALLION**
Payload: 36,000 lb.



■ **SIKORSKY SKYCRANE**
Payload: 20,000 lb.

GYROPLANES



■ **CARTER HELIPLANE**
Payload: 45,000 lb.



■ **GBA GYROLIFTER**
Payload: 40,000 lb.



■ **GYROPLANE 2050 (CONCEPT)**
Payload: 2,000,000 lb.

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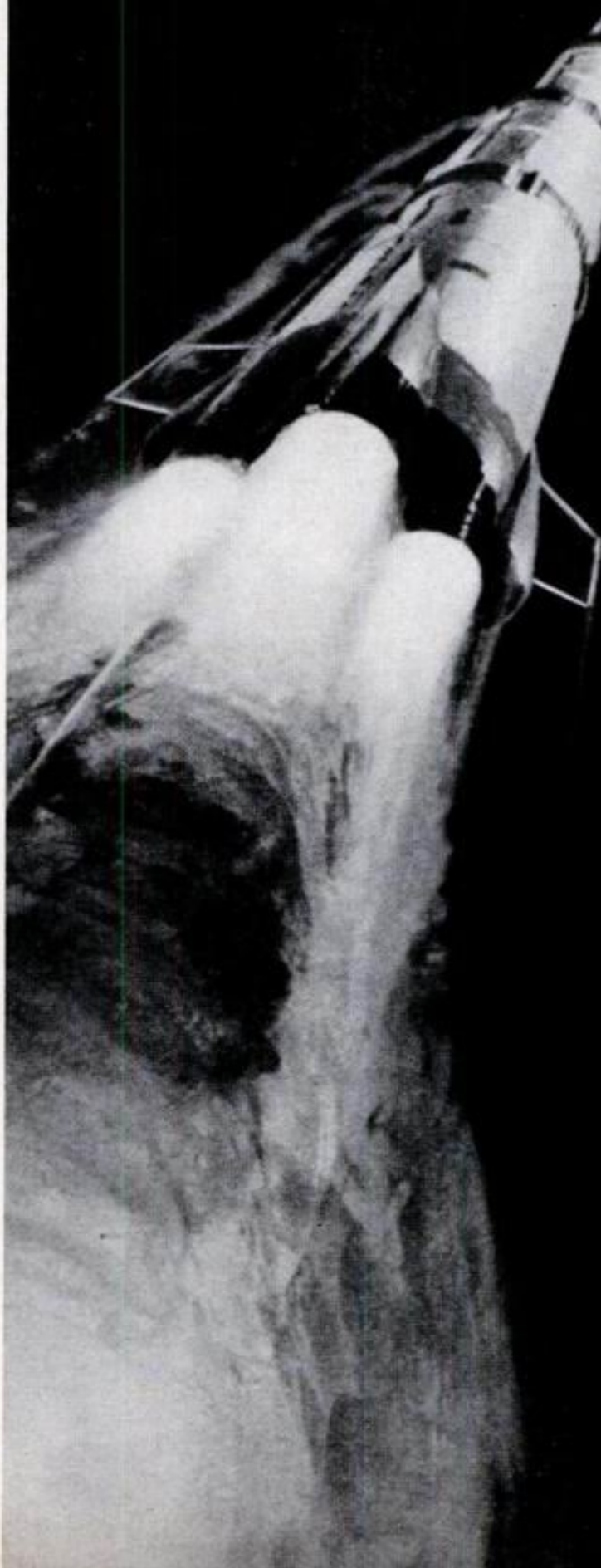
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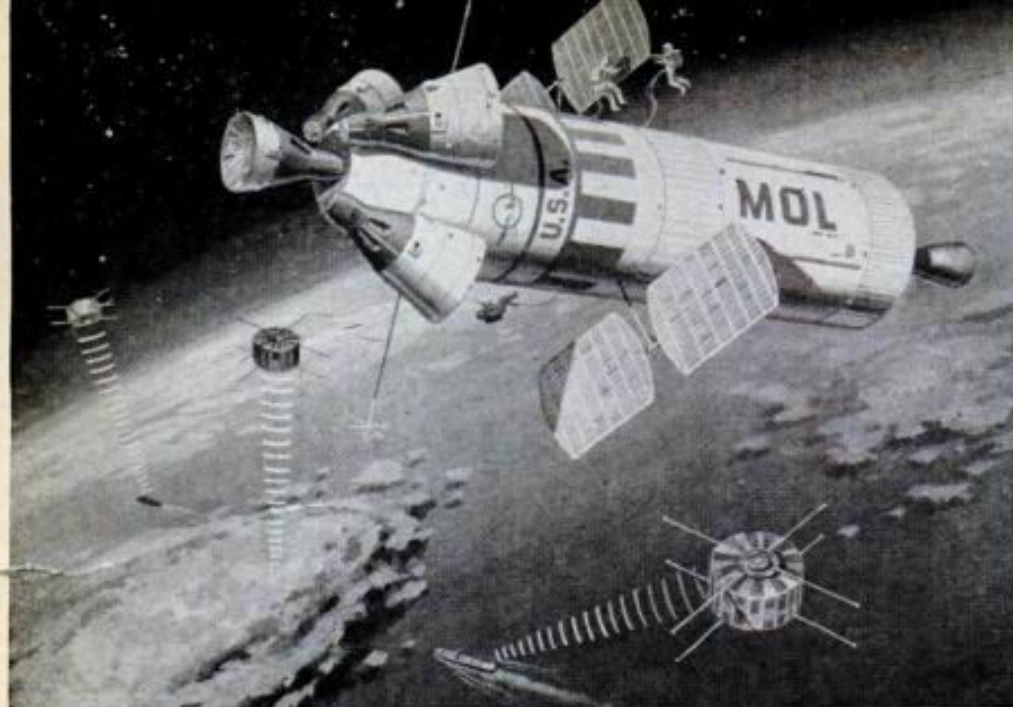
THE NEXT FIVE YEARS IN SPACE

John Glenn rocketed into orbit just five years ago this month. Since then we've successfully launched two-man crews, completed rendezvous and docking maneuvers. What will the *next* five years bring?

By WILLY LEY

FIVE YEARS AGO, on Feb. 20, 1962, Col. John Herschel Glenn became the first American to orbit the earth. His Mercury capsule, *Friendship-7*, went around three times. The flight is remembered vividly for the trouble he had. Toward the end, an indicator light falsely announced that the heat shield was loose.

Five years ago the main question was whether the flight could be done. For the next five years, with all eyes focused on the moon, the question is *when* it will be



1968

FIRST MOL (Manned Orbiting Laboratory) will be orbited. Air Force astronauts, first military men in space, may stay aloft 30 days. In background are unmanned navigation, weather and communications satellites

done. How attitudes change so soon!

The best guess is that the LEM (Lunar Excursion Module) of the Apollo spacecraft will touch down late in 1968 or early in 1969.

Saying that there will be a base on the moon or that a large manned space station will orbit the earth is no longer a "prediction." It is simply a statement about things to come.

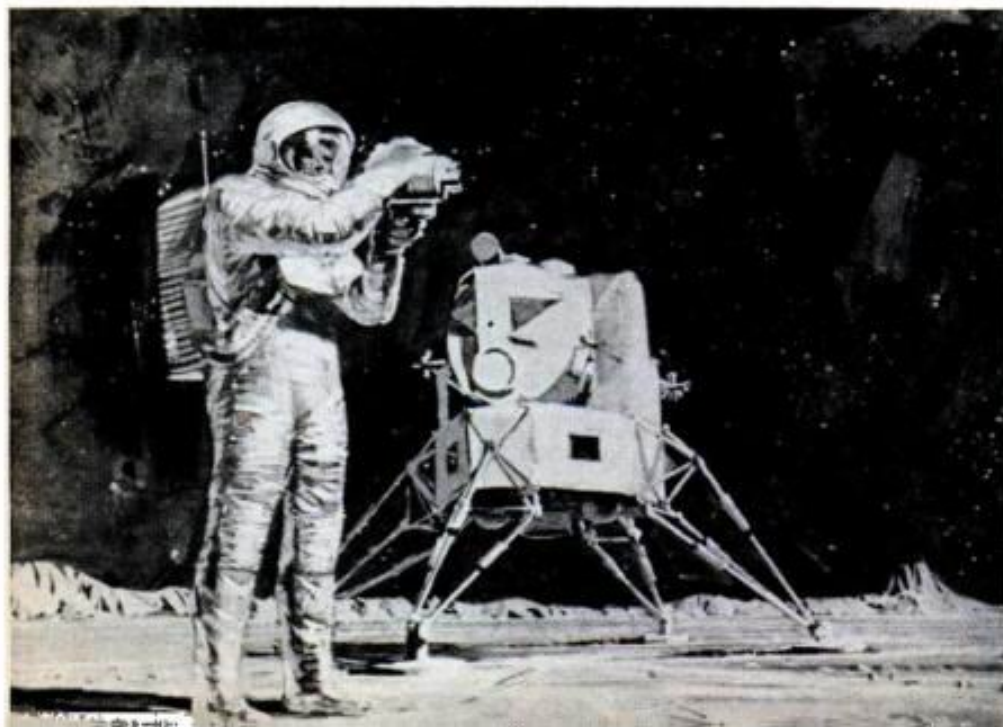
The build-up for all these events began 10 years ago when the first artificial satellites went into orbit. Since then, many things have been accomplished. The U.S. Navy reported in 1966 that its system of navigation with the aid of satellites is both operational and accurate. Communication satellites are operational and so are weather sat-

ellites. The Armed Forces have satellites in orbit that will report on the takeoff of large missiles, and they have other satellites that will report on atomic explosions in space.

In the years to come many more unmanned satellites and space probes will be put into space, but the big events will be manned space flights.

Considered "impossible" by many critics as late as 1960, manned space flight has proceeded smoothly to rendezvous and docking in orbit. The only drawback so far is in the space suits; they are not versatile enough. There may have to be at least three kinds of space suits: for inside the capsule, outside the capsule and on the moon.

One would be a general-purpose suit

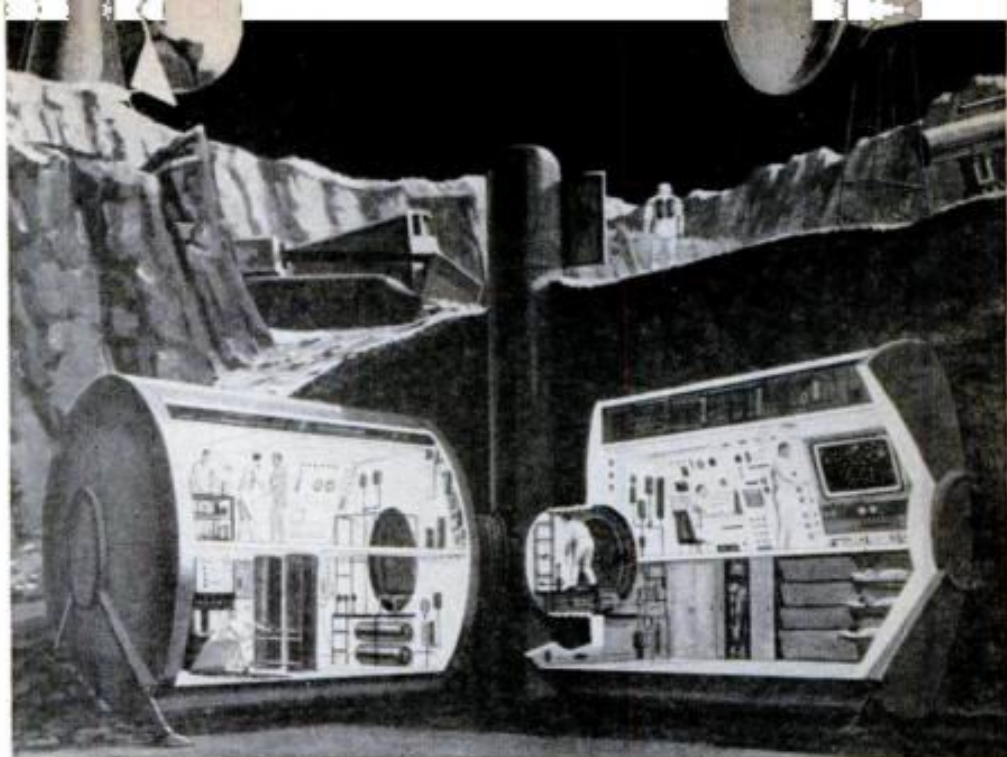


1969

FIRST LANDING on moon by American. One astronaut will leave LEM (Lunar Excursion Module) and explore surface, collecting samples and photographing area. After four hours, another astronaut will relieve him

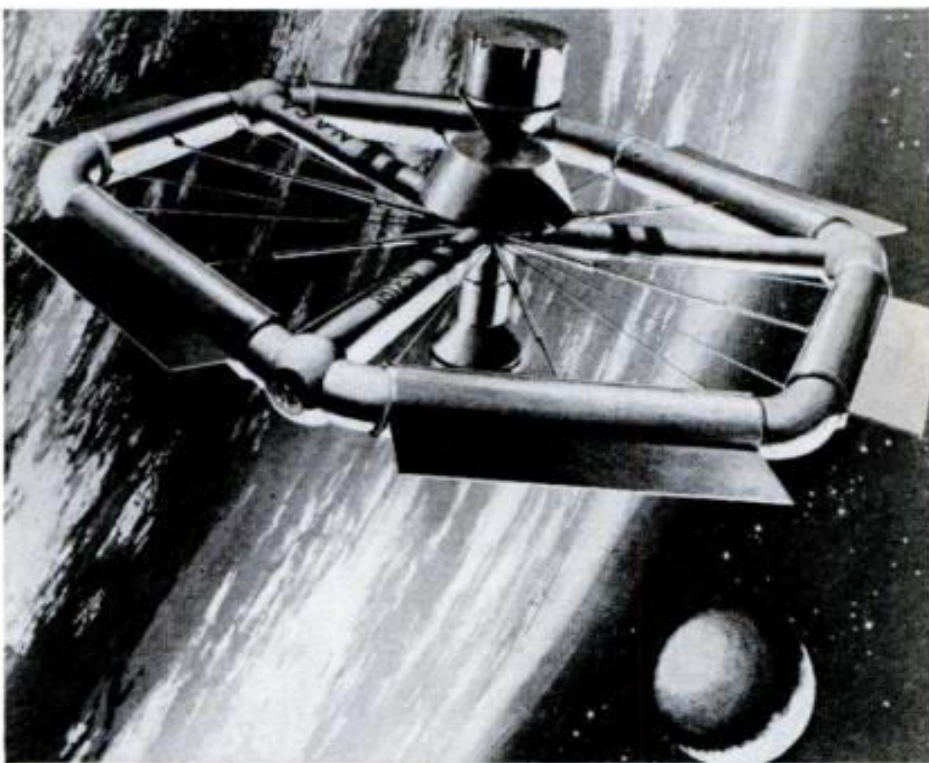
1970

LUNAR RESEARCH LAB operates. Here experiments under lower gravity conditions and complete vacuum can be carried out. U.S. industrial firms have already prepared list of projects they'd like to try on moon



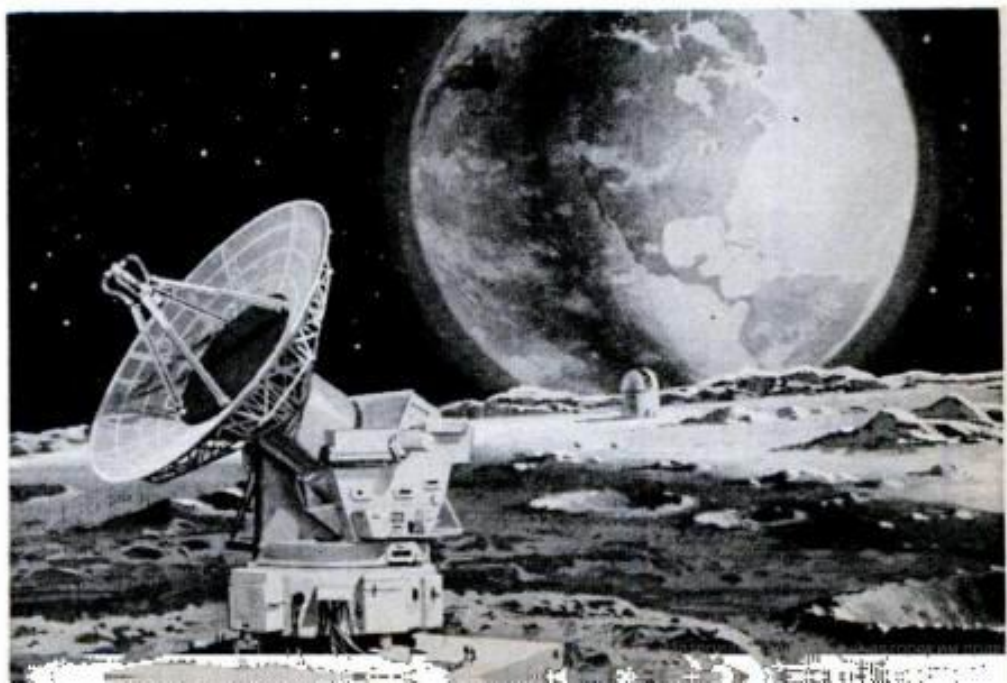
1971

SPACE STATION. First large manned station may be mongrelized from spent stages of rocket boosters or created new for permanent orbit where manned "earth-watching" or other experiments can be carried on



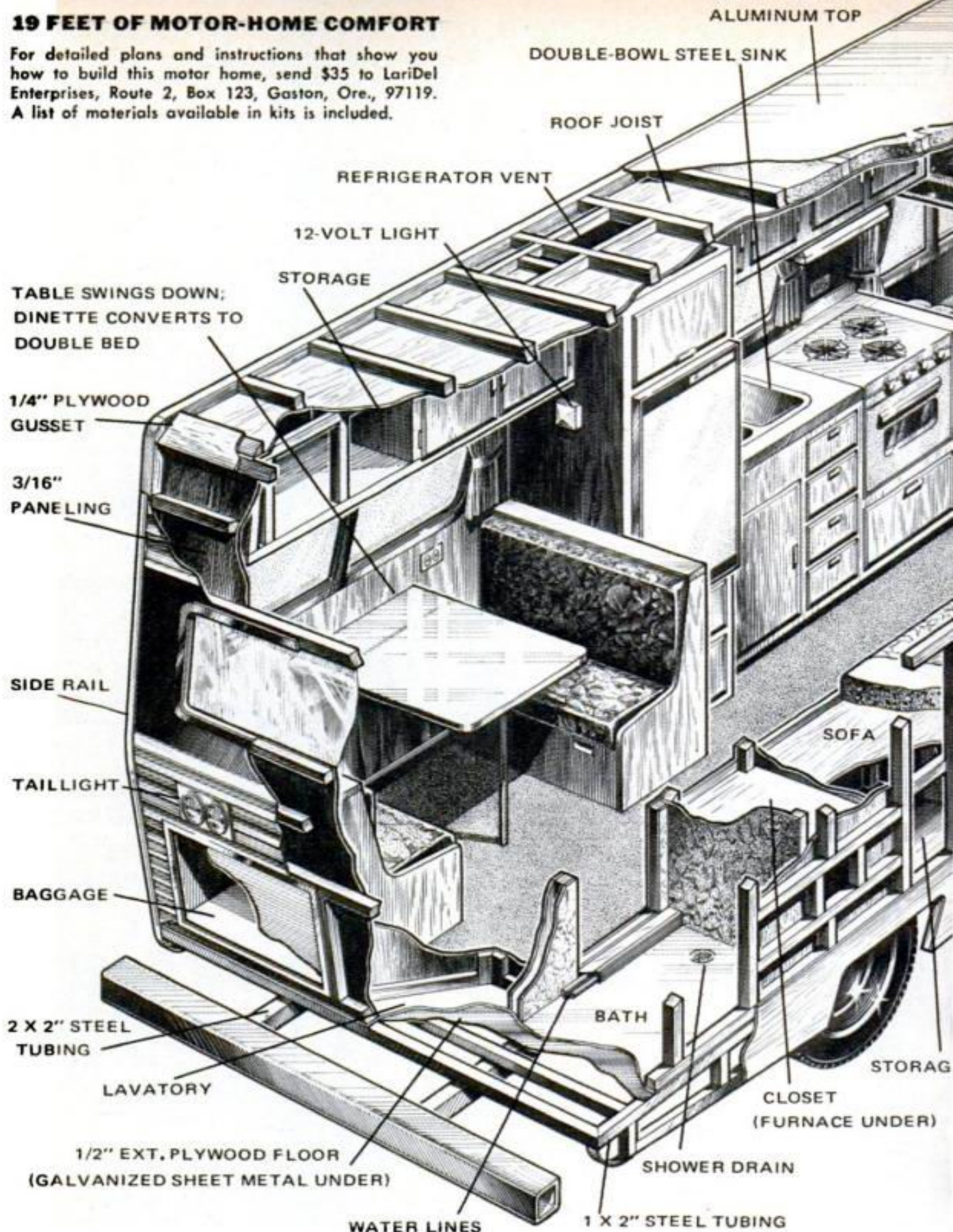
1972

RADIO TELESCOPE and astronomical observatory will be established on moon. They may, under lunar conditions, discover things that would be impossible to find by observation from earth due to gravity, atmosphere



19 FEET OF MOTOR-HOME COMFORT

For detailed plans and instructions that show you how to build this motor home, send \$35 to LariDel Enterprises, Route 2, Box 123, Gaston, Ore., 97119. A list of materials available in kits is included.

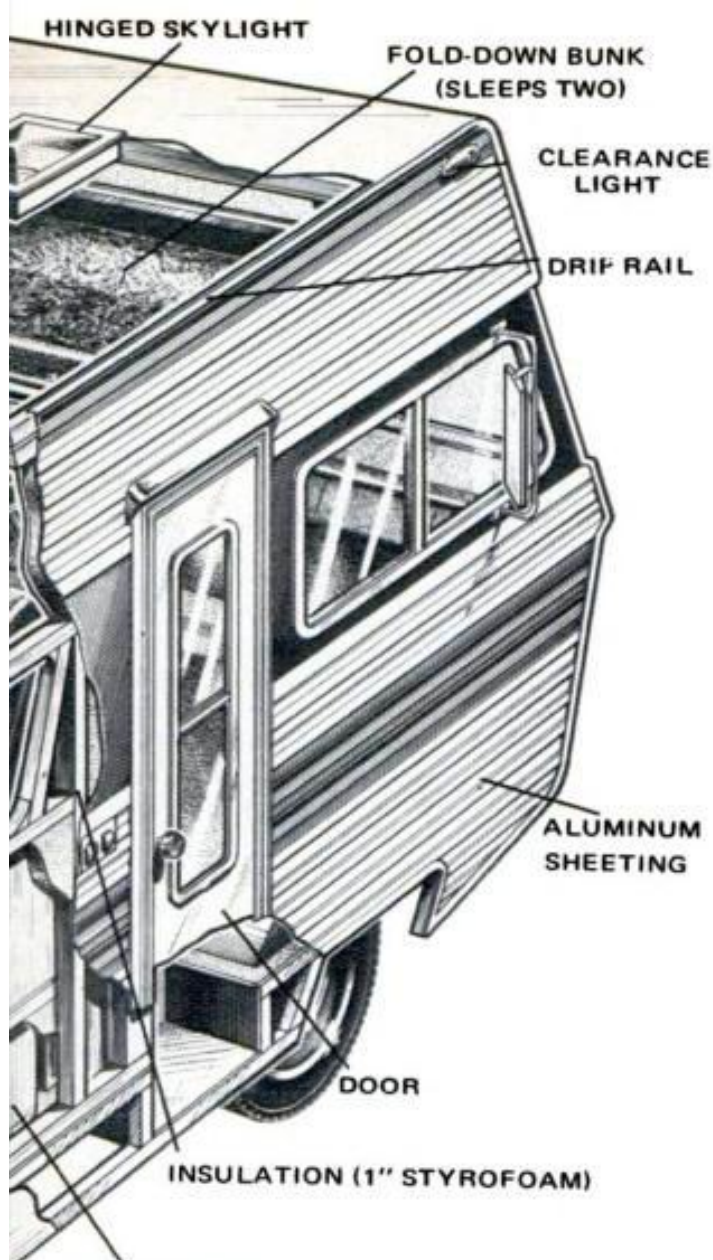


even rent three air-driven staplers for 120 days for \$130.) Exact price for the used chassis (Ford Econoline, Dodge, Chevrolet or GMC-type van with 108-in. wheelbase) can't be quoted in advance. Since the body will be torched off, appearance doesn't matter. Neither does the condi-

tion of tires or wheels; they'll be replaced with heavy-duty equipment. Engine, frame and drive train are all that count. If you shop wrecking yards for a van with a damaged body you can expect to pay from \$600 to \$1100.

If a cutting torch isn't available for re-

POPULAR MECHANICS



WATER TANK

moving the old body, the job can be done with a chisel and a 3-lb. hammer. Complete instructions and the blueprint for welding the floor frame (18 ft. x 7 ft. 3 in.) make it a simple job for a welder, if you don't have the equipment.

The springs must be beefed up with the addition of two extra leaves. You can do the job right and save money by purchasing from a wrecking yard the main leaf and second leaf for your make of chassis. With a torch, cut off eyes at the ends of the main leaf; keep it as long as possible. The springs are dismantled and an additional leaf inserted between the main and second leaf; another is inserted between the second and third leaf from the top. New U-bolts and center bolts button up this job.

Wheels should be replaced with heavy-duty rims, 8.00x15 in. reversed. Tires may be H 70-15 wide track four-ply nylon or

[\(Please turn to page 192\)](#)



CHASSIS IS READY for sidewalls after old van body has been cut off. Frame is widened and lengthened



SIDEWALLS ARE FRAMED on shop floor. Jig for framing is made on 1/2-in. plywood later used for floor



PREFINISHED PANELING is stapled to sidewall frames after glue bead has been applied to studs



LEFT SIDE WALL ready for aluminum exterior "skin." Styrofoam (1 in. thick) fits snugly between all studs

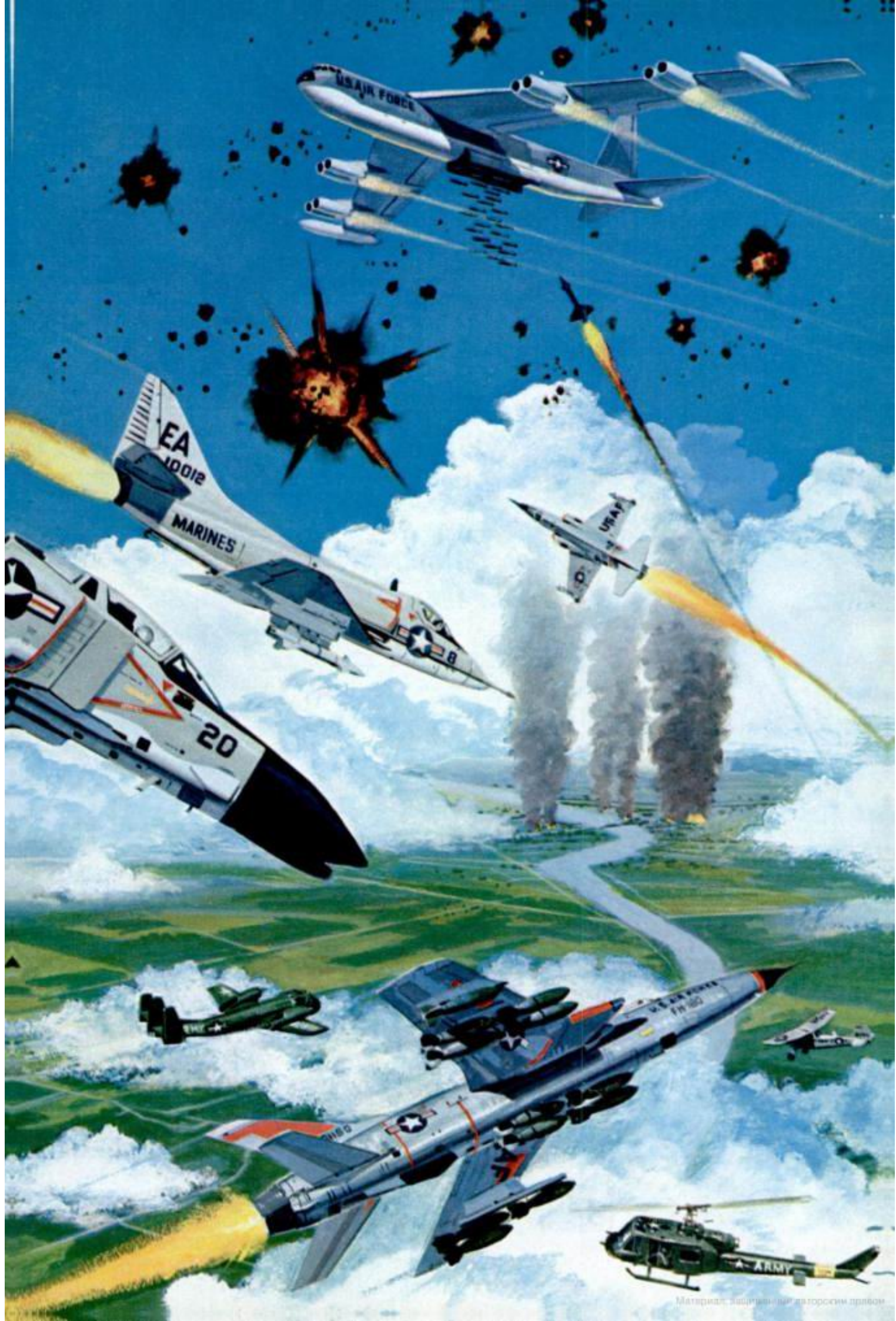


U.S. Helicopters in Vietnam





VALIGURENY





Daytona Beach Resort Area photo

Looks like a convention in Daytona Beach; they're all hovering on the Hydroair Vehicle's air cushion

PM DITOR RIDE TH CAR

By John Linkletter

DOWN IN DAYTONA BEACH—a city whose name is synonymous with speed—there's a new machine racing over the famed speedways, the swamps and the ocean.

It's the Hydroair Vehicle, one of the newest of a steadily growing fleet of ground-effect machines and probably the largest one in the country—or, for that matter, in the world.

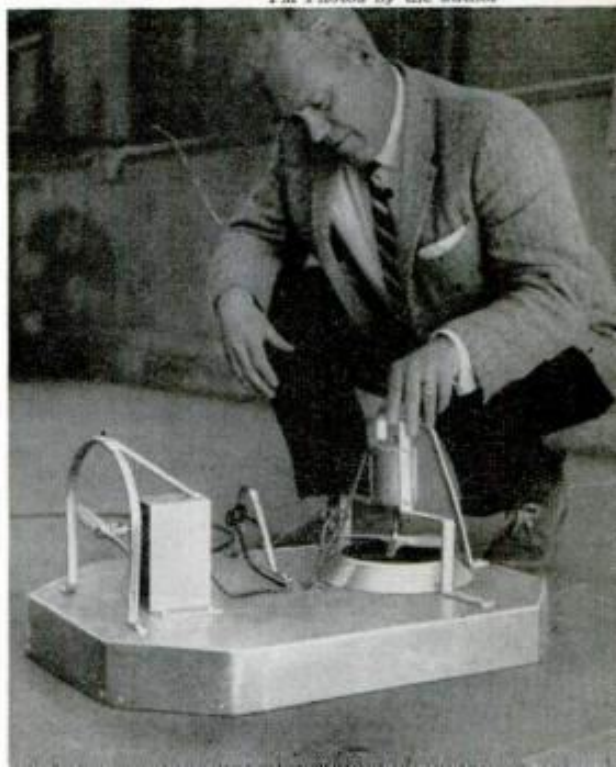
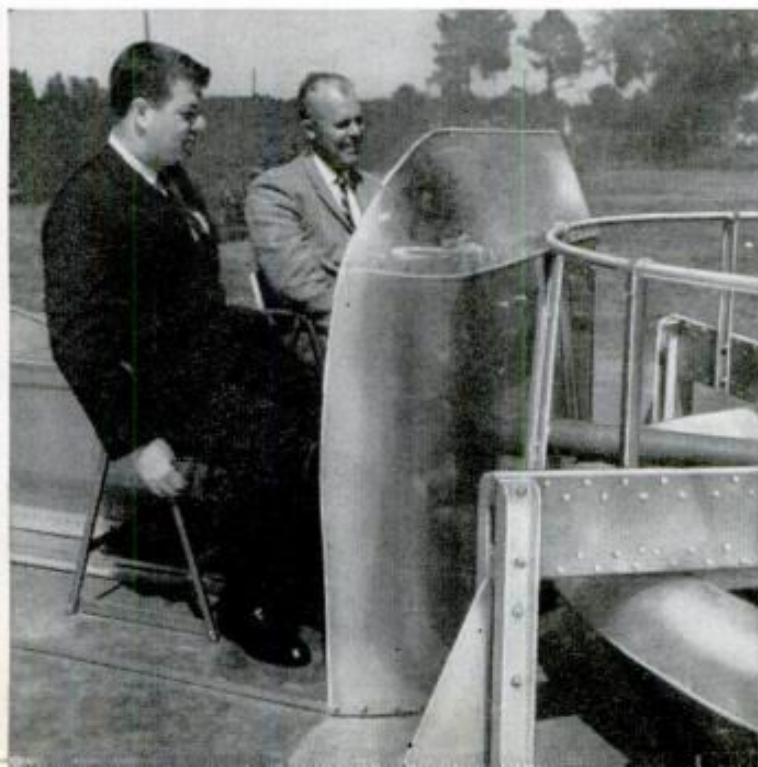
These machines are sprouting around the

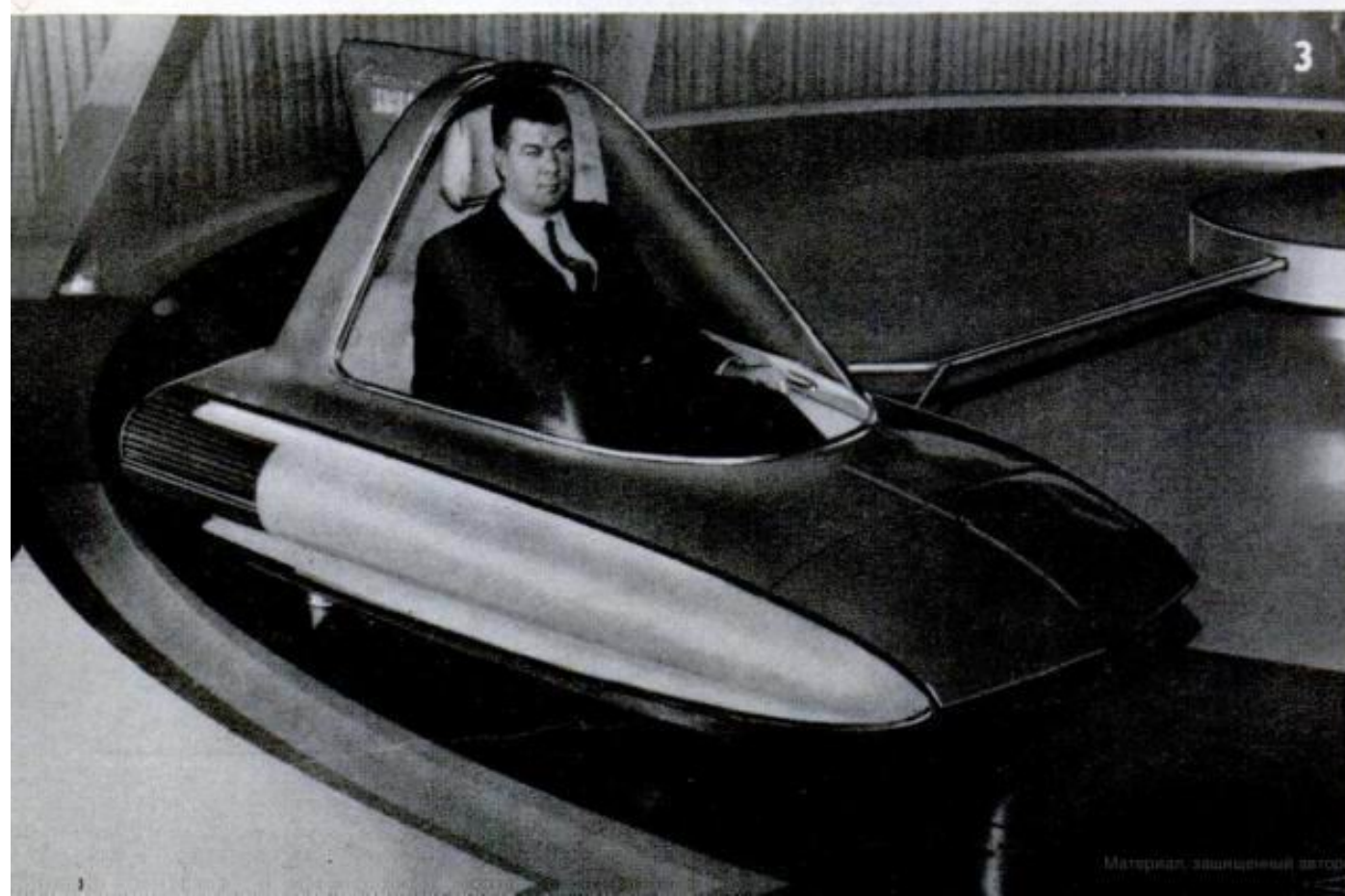
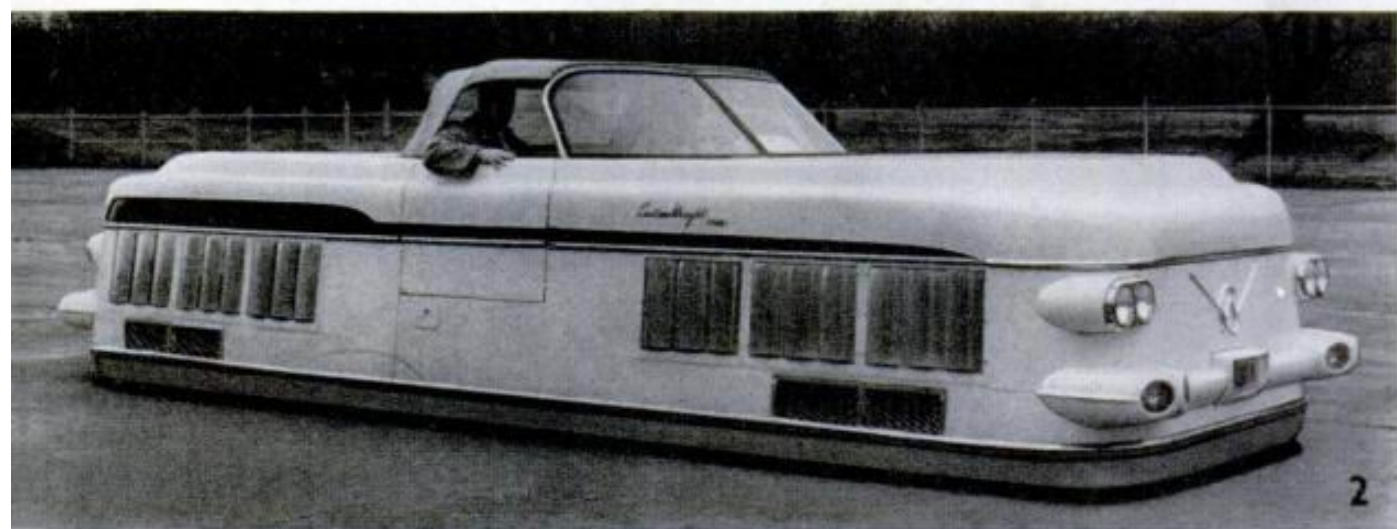
country like Iowa corn in the spring; one industrial firm estimated that some 300 existed at the beginning of the year. While they're generally referred to as air cars or air scooters, the more accurate general designation is air-cushion machines or ground-effect machines.

A few weeks ago I rode the Hydroair Vehicle. Carl W. Bollum, Sr., president of Spacetrronics, Inc., sat at the controls—wisely keeping me in a passenger status.

Spacetrronics president Bollum shows me how easy it is to drive and displays electrically-powered model

PM Photos by the author





Bell Helicopter's experimental Air Scooter is a plenum chamber type. Its 12-horsepower two-cycle engine lifts the craft (and a research engineer) 2½ inches



Bell Helicopter Corporation photo

At that time, his firm (lately moved from Washington, D. C.) was still negotiating land leases for manufacturing and testing, so there were no full-throttle passes over the Halifax River or the hard sand beaches. However, with Bollum expecting to hit 100 miles an hour over water, I'll be content to pull up a beach umbrella along the sidelines and watch those speed runs—which should be taking place about the time you read this article.

We hovered and moved the craft cautiously within the confines of a road-machinery lot. While the vehicle rode on its self-generated cushion of air about five inches above the ground, I meandered

about its 32 by 24-foot deck and jumped up and down—with an admitted lack of grace—along the edges. It was solid.

This was the fourth ground-effect machine that I had accompanied into the wild blue—some as high as six inches! (Back at the office, I'm known as the astronaut of the air blast.) In all four machines, there are certain characteristics of the ride that are quite similar.

Riding a ground-effect machine isn't like riding an auto—there's no transfer of road bumps to the passengers. You sit on the craft and watch stones and curbs disappear beneath the machine, expecting all the time to feel the bumps while the air-

1. Even the bravest citizens took cover as I drove Dr. Bertelsen's Aeromobile back and forth through the Neponset streets

PM Photo by Joan Linkletter

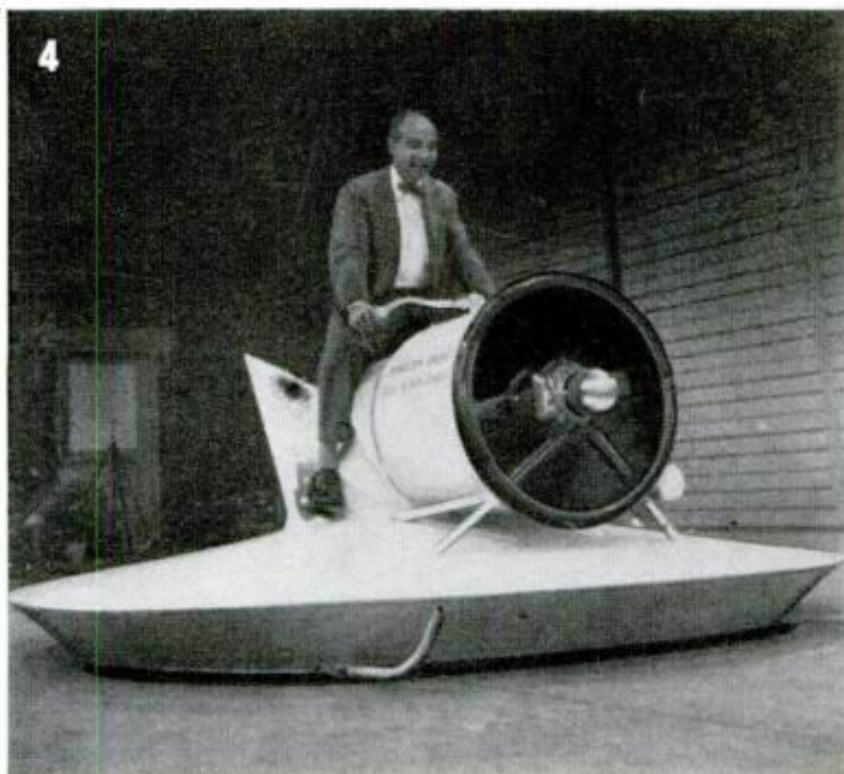
2. This time I rode under a jaunty canvas top alongside Don Swem who operated the Curtiss-Wright Air-Car over rough test grounds

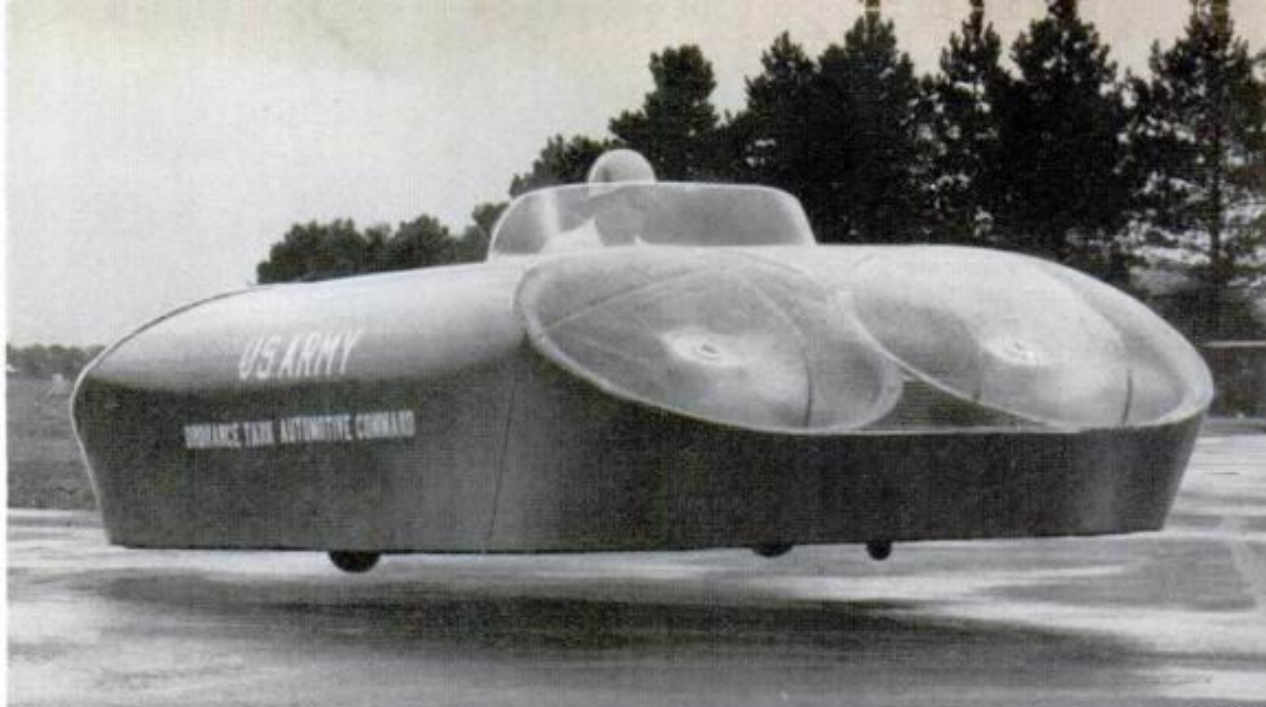
PM Photo

3. I couldn't decide whether this was like flying a jet or lying in state. Levacar slides a fraction of inch above metal road

Ford Motor Company photo

4. Tall in the saddle is another high-flyin' PM editor, Dick Dempewolf who maneuvered the Princeton University Air Scooter





UPI photo

One of the machines demonstrated at the Princeton University symposium on ground-effect phenomena was the U. S. Army vehicle built by the National Research Associates. Delegates to the session shared information

borne platform moves on as smoothly as a dab of butter in a hot skillet.

And it isn't like an airplane ride—you don't have the feeling of positive control that comes from the movement of air at high speed over aerodynamic control surfaces. (However experienced operators can control them.)

One way to describe the ride, perhaps, is to compare it to sitting on a piece of plywood on a bunch of loose marbles. The vehicle will turn, move sideways, slide downhill and cavort just that readily on its cushion of air. But it doesn't matter whether the surface below is concrete, mud, dirt or water—the machines move

over all with equal ease because they never touch the surface.

The 5300-pound Spacetrronics vehicle, for instance, is designed specifically for over-water use. Made of aluminum (Alcoa showed its faith in the machine by supplying the metal for the prototype), it has a one-foot thickness of Styrofoam under the deck to provide flotation. The aluminum apron hangs down another foot below the plastic, forming a large open space much like an inverted pie plate. Air blasted into this chamber—known as the *plenum*—forms the air cushion on which the craft rides. Pressure in the air cushion is nine pounds per square foot.

Typical of the forward propulsion systems that appear on current ground-effect machines are these:

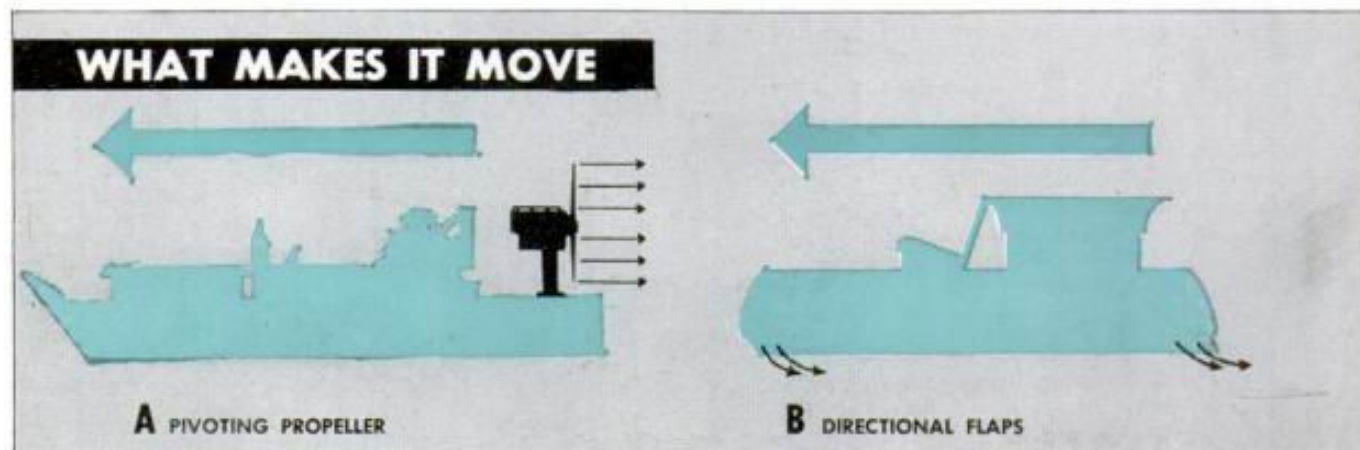
A: Engine and propeller independent of the craft's lift system, as in the Spacetrronics Hydroair Vehicle

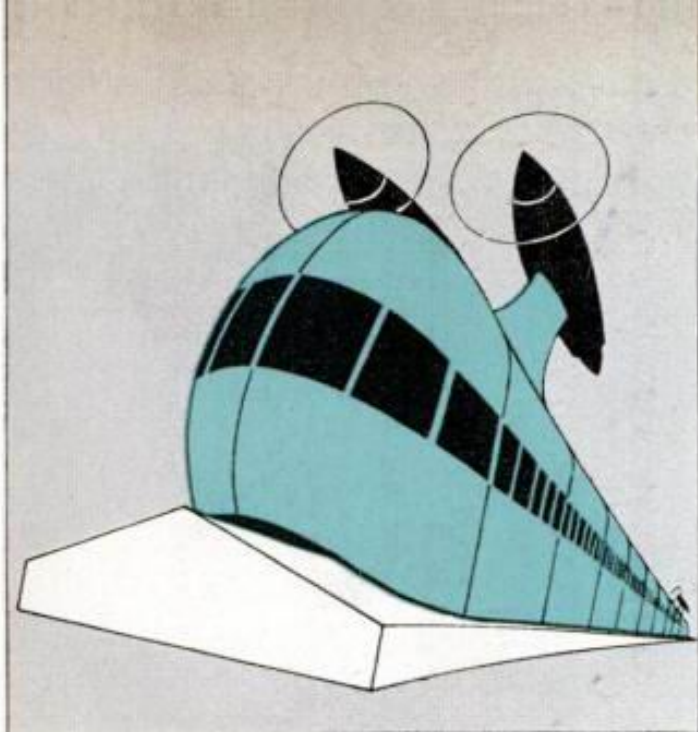
B: Flaps extending downward from outer edge of machine to deflect air flow, as on Bertelsen Aeromobile

C: Louvers in chamber walls direct the stream of air bled from chamber, as in Curtiss-Wright Air-Car

Methods of utilizing the air pumped into the ground-effect machines to achieve lift are generally these:

D: Air goes into large open chamber in which pressure is relatively constant, as in Hydroair Vehicle





From Spacetroneics drawing
Futuristic conception from Spacetroneics is a train that rides air cushion on triangular concrete rail

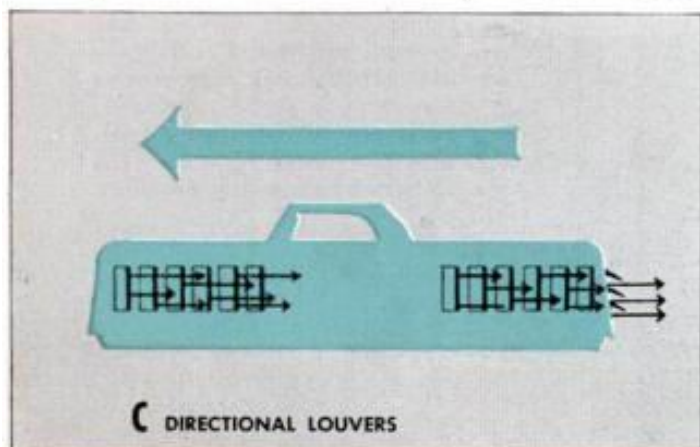
The plenum chamber is the simplest of the ground-effect machines—and the least expensive to manufacture, Bollum points out. He uses the air in the plenum only to achieve lift; propulsion of the craft depends on a second engine and propeller mounted on a stand at the stern of the Hydroair Vehicle. The unit swivels to direct the machine as the operator turns a wheel.

Bollum plans to try a rudder behind the propeller for control. He also will add two more horizontal fans—powered by 180-horsepower helicopter engines—near the rear of the craft and replace the present industrial engine with a 240-horsepower Lycoming to power the forward fan.

E: Air is directed to slot around edge and is ejected as a high-velocity air curtain, as in the Aeromobile

F: Air pressure under the craft is lowered in stages so that there's a minimum of loss into atmosphere

G: High-pressure air entering simple levapad lifts pad off rail a fraction of inch, as in Ford Levacar



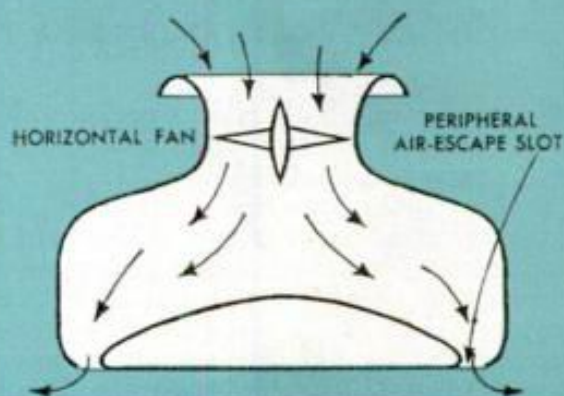
JUNE 1960

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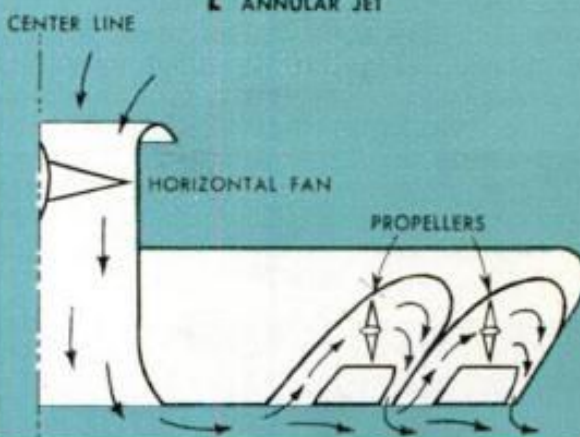
WHAT MAKES IT RISE



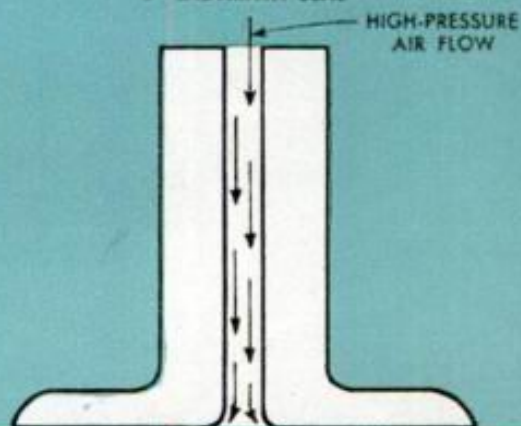
D PLENUM CHAMBER



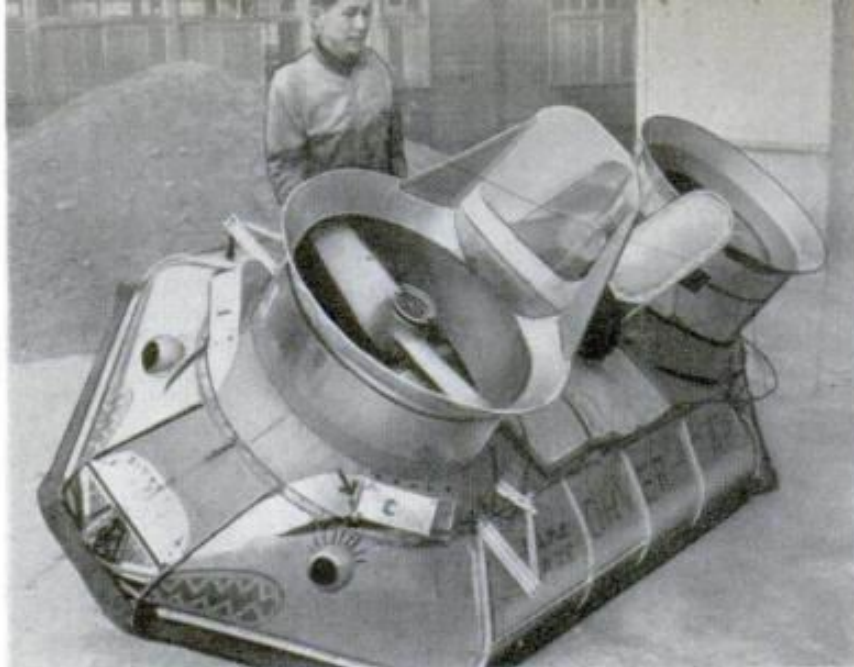
E ANNULAR JET



F LABYRINTH SEAL



G LEVAPAD



UPI photo

Tokyo version of ground-effect machine was built by a mechanic. It has two six-horsepower engines and is named *Kamekaze* (the term means turtle wind)

Spacetrronics has plans for a considerably larger craft in the future, as well as for a smaller sports model this year.

Bollum spent nine years with the U. S. government as an engineer in the field of guided missiles. He became interested in ground-effect craft through contact with inventor Walter A. Crowley in Washington. One of the earlier Spacetrronics experimental craft is on exhibit at the Smithsonian Institution in Washington, D. C.

There's another common method of utilizing the air mass by directing it to a peripheral slot beneath the machine so that there's a high-velocity curtain of air shooting downward from the slot, or *annular jet*.

I rode on this type of craft in the town of Neponset in western Illinois, where a local physician, Dr. William Bertelsen, has developed a very workable machine in his

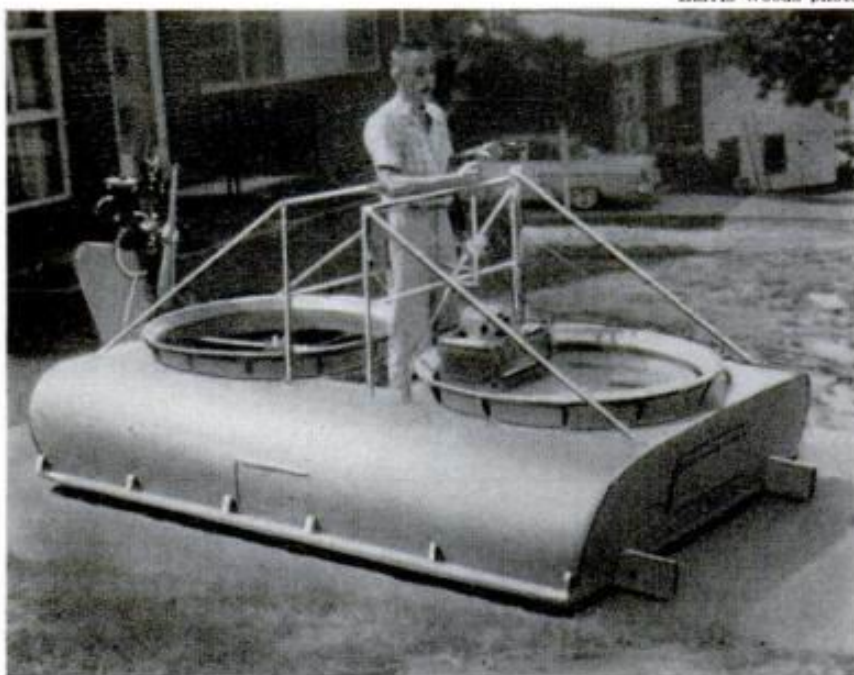
spare time with his father's help. The doctor's aim is to create a vehicle that will take him any place in the countryside where people happen to go to break arms, have babies or otherwise need medical attention.

After building and testing a number of models, Dr. Bertelsen decided that the annular jet best answered his need. As a matter of fact, the control system he developed utilizes the curtain of air that blasts downward from the peripheral slot. There are vertical flaps located on the outside edge of the slot which, when moved by the control stick, deflect the airstream to give the craft thrust in any direction and turn it.

I don't know how many hundreds of hours the doctor and his father had spent perfecting the machine, but they gamely risked all in the hands of this novice by al-

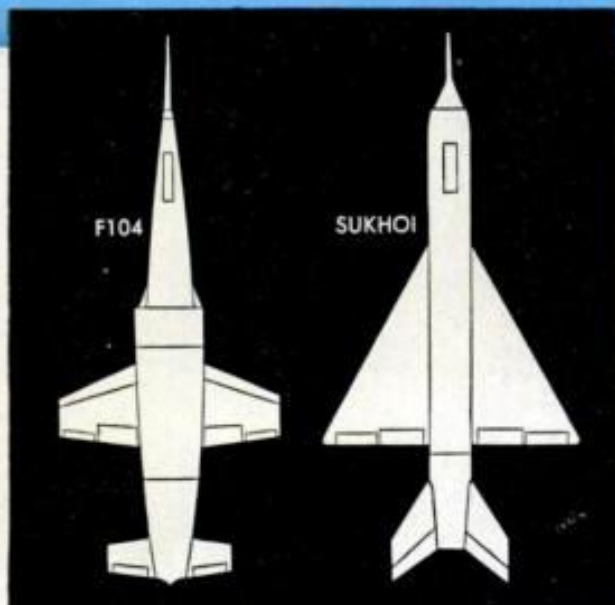
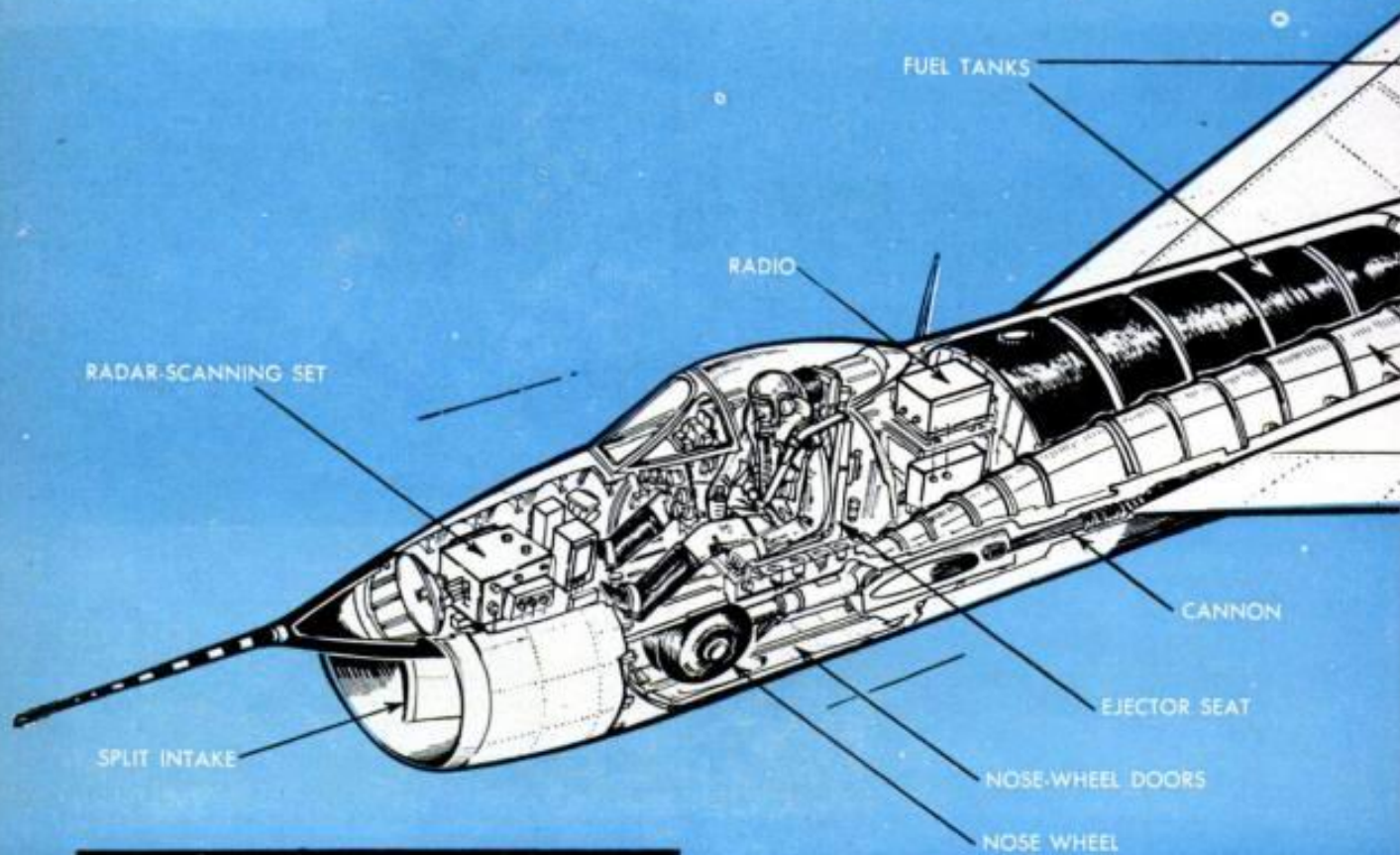
(Continued to page 228)

Harris Woods photo



Harris Woods of Smyrna, Ga., tests machine he and G. W. Wolfe built. Though two engines were planned, a single 25-horsepower plant proved sufficient to elevate the annular-jet craft. A 15-horsepower engine propels it

RUSSIA'S ANSWER TO THE F104 "STARFIGHTER"



Sukhoi, Russia's first delta-wing production aircraft, has a different shape but the same function as F104

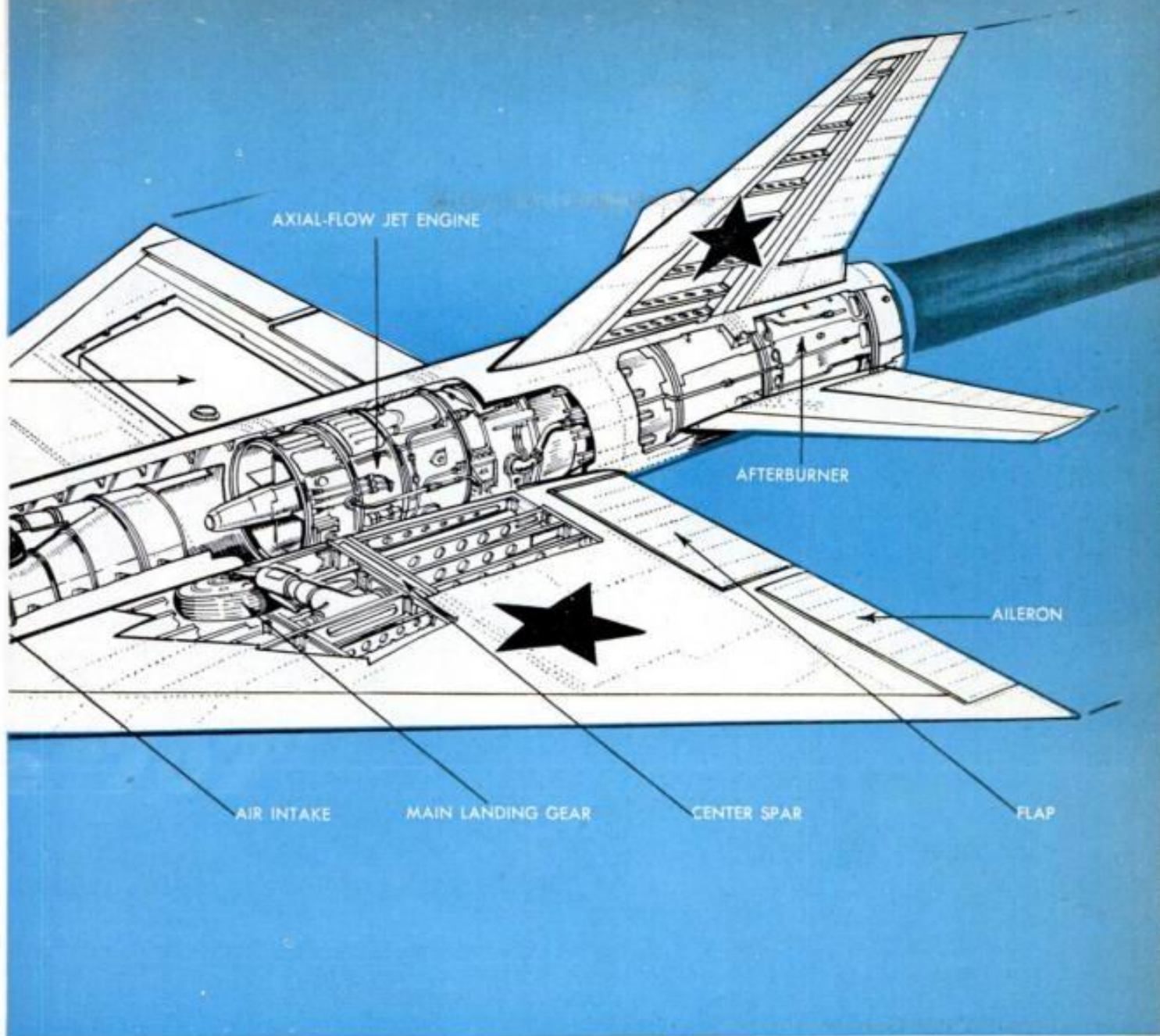
Illustration and text by Thomas Turner

RED AIR FORCE PILOTS are testing a modern piece of flying equipment called the Sukhoi. It is not unlike the breed of aircraft of which the U.S. Air Force's F104 is a member. Both planes (see drawings at left) are lightweight interceptors with similar characteristics, mounting similar armament and capable of similar high speed and maneuverability.

The new Russian aircraft first came to the notice of the West when three prototypes zoomed low over the heads of top research and development brass of the U.S. Air Force last year. Available photographs of the Sukhoi reveal streamlined thinking on the part of Russian designers.

Nearest resemblance to an American plane is in the nose intake of the Red aircraft, which is identical in function to the U.S. Navy's 1000-mile-per-hour F-8U Crusader. In essence, the pointed radar nose is placed over and ahead of the cheek

POPULAR MECHANICS



intake in a position where it can produce a shock wave that strikes the lower intake lip. This has the effect at supersonic speeds of providing a much more efficient low-speed air flow into the engine.

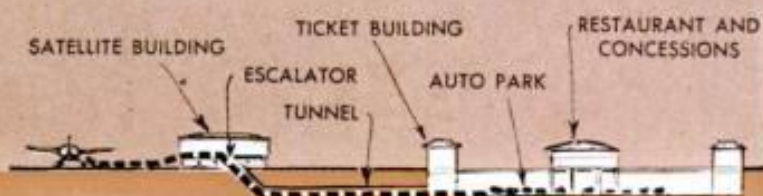
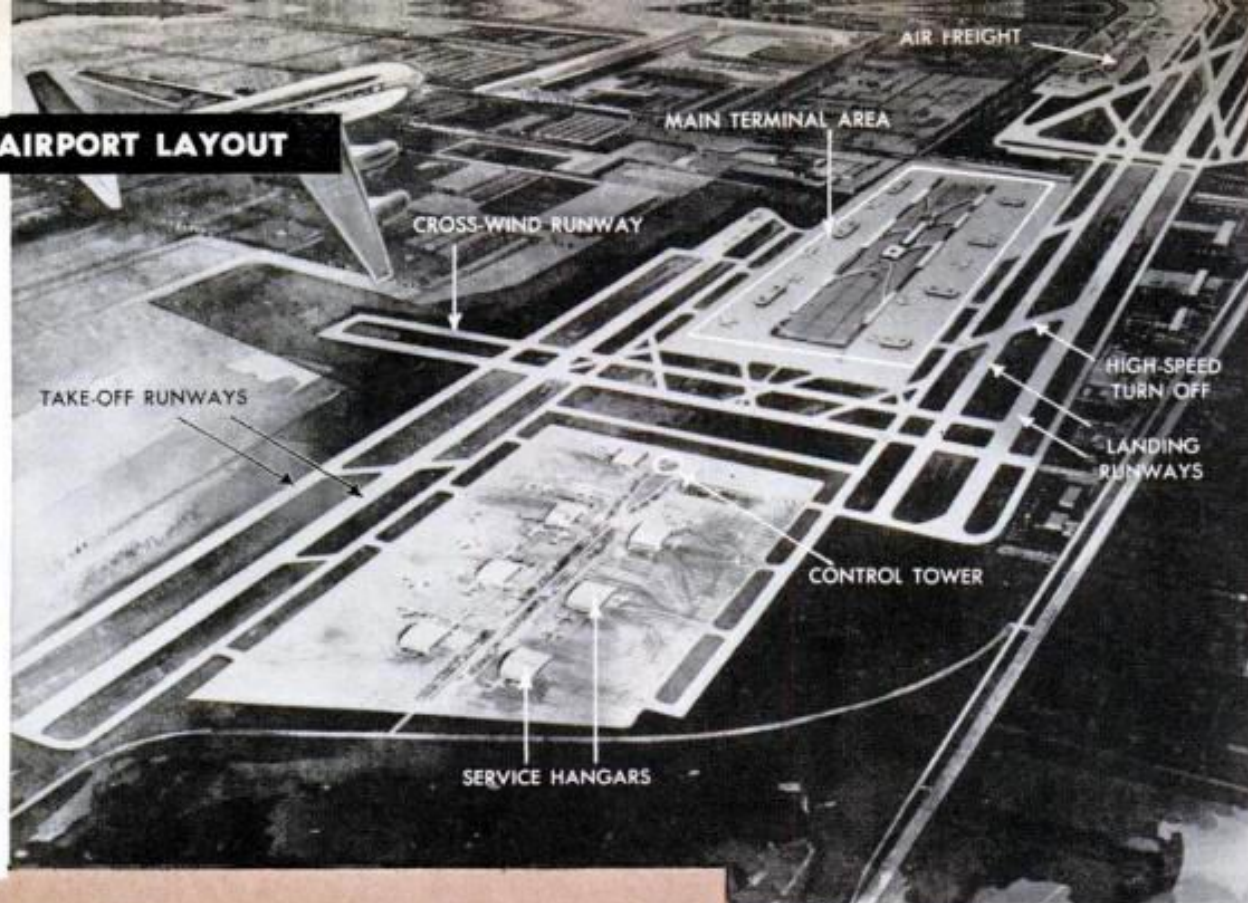
As in most Russian combat aircraft, visibility is good. The pilot sits forward of the wing's leading edge. A conventional tear-drop canopy with rear vision sits high on the fuselage. The cockpit is probably fitted with an open-type ejection seat, as in the MIG-15.

The Sukhoi is a clean, long tube with a delta wing of about 60-percent sweepback, plus a sweptback tail. Few delta-wing planes flying today have the luxury of a tail, with the notable exception of the British Royal Air Force Javelin, an all-weather fighter. Stability obstacles associated with pure delta, and its inherent problem of high landing angles, probably influenced Russian engineers to add a tail

in spite of higher resulting drag. The wing is small and appears to be thin. Landing-gear legs are housed in the wing but retract so wheels are stowed in the lower fuselage ahead of and below the engine. Two large cannons are mounted, one on each side of the fuselage, well back from the nose. Ammunition is near the Sukhoi's center of gravity.

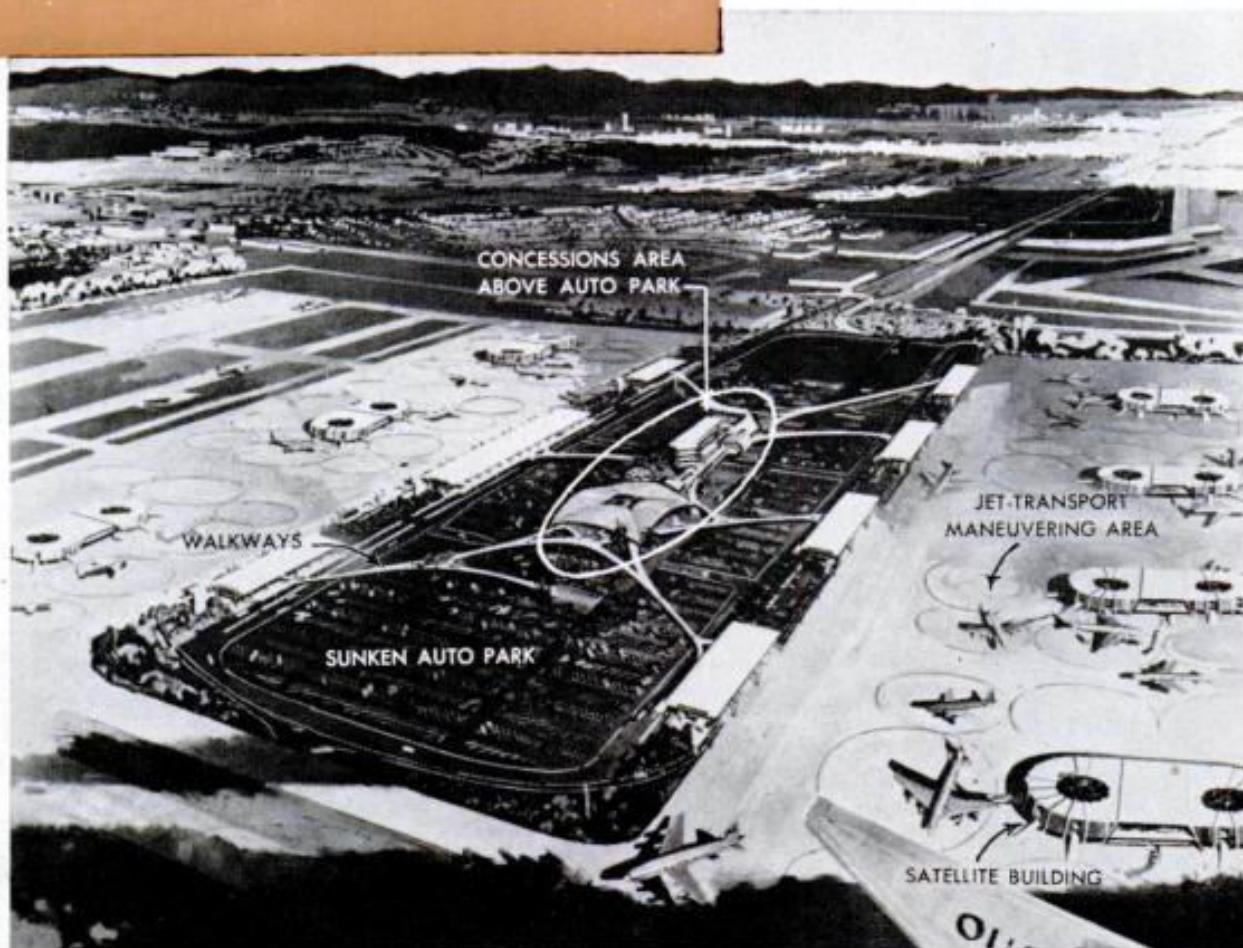
The rear lower line of the fuselage has a slight upsweep to give ample ground clearance and to make a shorter landing gear. Weight has been cut to a minimum, possibly by eliminating duplication of hydraulic systems. Safety devices are reduced, as in the MIG-Falcon which in the Korean War was two tons lighter than our Sabre Jet. If the Sukhoi's designers adhere to the minimum-weight philosophy, this aircraft may come up to a performance level equivalent to the Starfighter, possibly in the Mach-2 category.

AIRPORT LAYOUT



By late 1959, Los Angeles will have this airport designed for the jet age. Take-off and landing runways are widely separated

Close-up of terminal area shows satellite buildings clustered around concessions area. Detail at left shows the passenger route



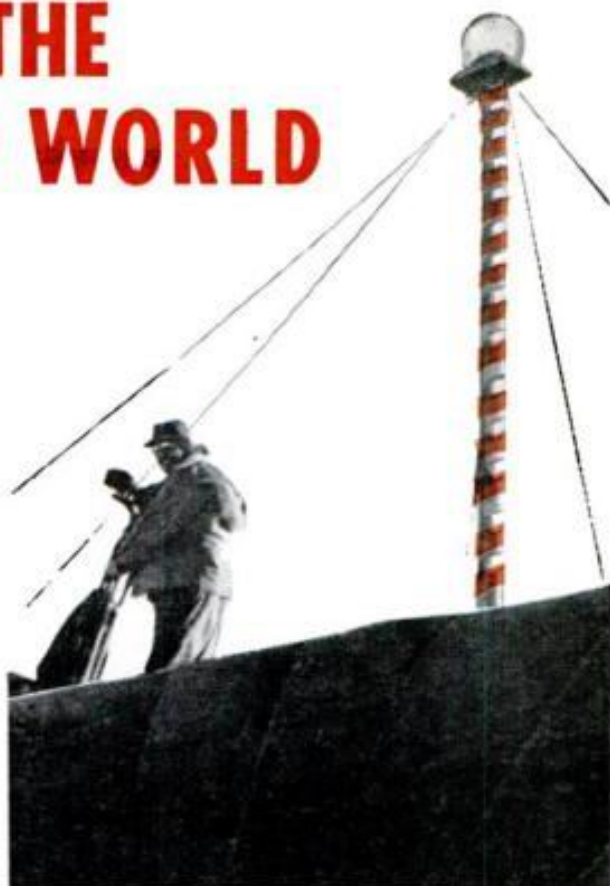
OUR HOME AT THE BOTTOM OF THE WORLD

By E. H. Hubel

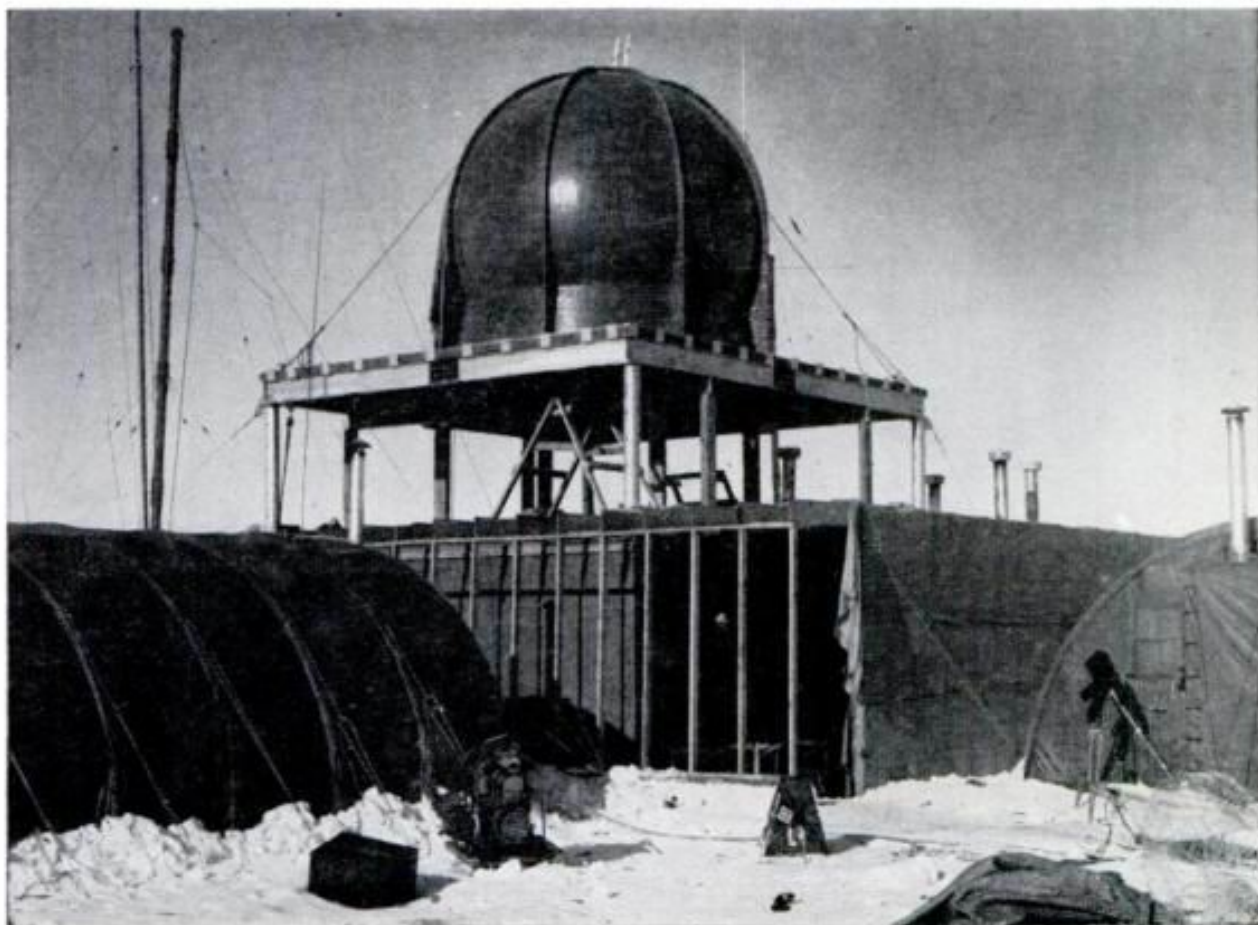
Utility Man's Chief, U. S. Navy

OUT ON ANTARCTICA'S 10,000-foot icecap, eight scientists and eight Navy Seabees are sitting out the bitter six-month Polar night—smack-dab on the South Pole. For nearly a thousand miles in every direction Polar storms drive granular snow across the white "desert" with stinging force. Temperatures read in the 120 degree-below-zero range. Shifting auroral draperies emblazon an onyx sky. The silence, when the wind is still, is the silence of outer space.

Until now, no living creature has dared face the rigors of winter night on the South Polar plateau—much less the high frigid region near the Pole, itself. The men living there, led by Dr. Paul A. Siple, senior scientist of our "Deepfreeze" expedition, are trained, hardened Polar experts comprising the United States' International Geophysical Year South Pole team. Their camp, which I helped to build last November and December, is a snug system of buildings and tunnels largely covered by



Red-and-white-striped shaft marks the location of the South Pole. Atop the pole is an inverted fish bowl. Big dome on stilts, below, houses radar for tracking weather balloons released twice daily



drifting snow. Inside temperatures are nearly as warm as your own home. Hot and cold running water (produced from blocks of snow), showers and recreation facilities provide comforts never heard of in that bleak ice wilderness.

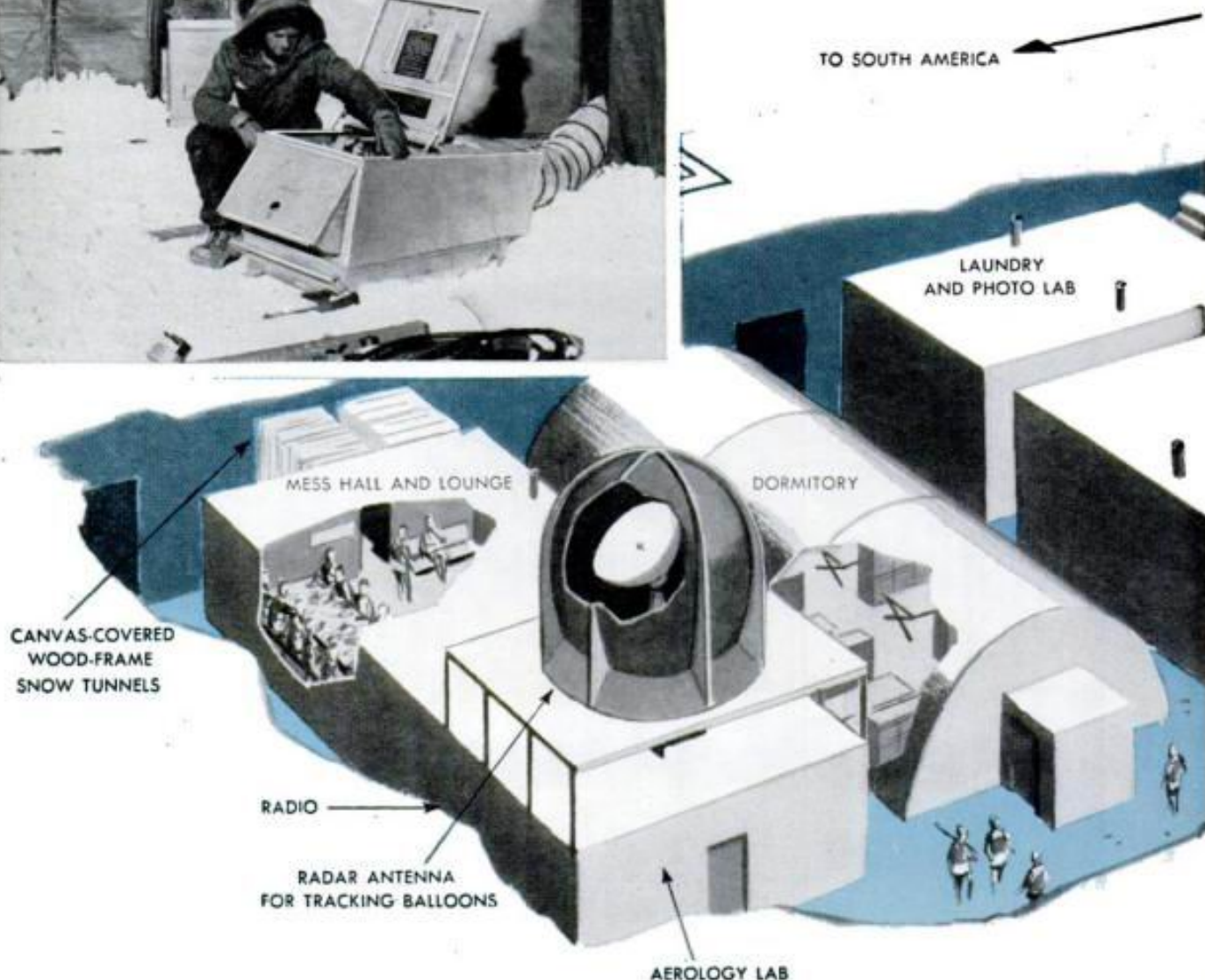
Until Admiral George Dufek, Commander of Task Force 43, landed on the icecap, no one was sure that a base could be built on the South Pole. Five hundred tons of material including a 17-ton D2 tractor, a weasel, nine big prefabricated buildings, plus 10 tons of food and 15,000 gallons of fuel to last 16 men more than a year, had to be moved 700 miles up from sea level to the two-mile-high center of the continent. Hauling that amount of material up the heavily crevassed ice of the Great Beardmore Glacier—which provided a gateway ramp to the Polar plateau for old-time ex-

plorers like Scott and Shackleton—was out of the question. It was doubted, too, that heavy ski-planes could take off or land on the deep, soft drift up there. No one knew what to expect. Plans called for air-dropping everything—including men if it became necessary—from huge Air Force C-124 Globemasters.

As it developed, Antarctica's central crust was solid enough to support our ski-equipped R4Ds and P2Vs, and these became taxis for men and light materials, ferrying back and forth between the ice runway at McMurdo Sound and a smoothed-out strip of snow that we called "Ike's Pike" at our Pole base. It was tough going. Temperatures at the Pole, even during Antarctica's "summer" months of November and December ranged from 30 below to 8 above zero. Skis froze solidly to



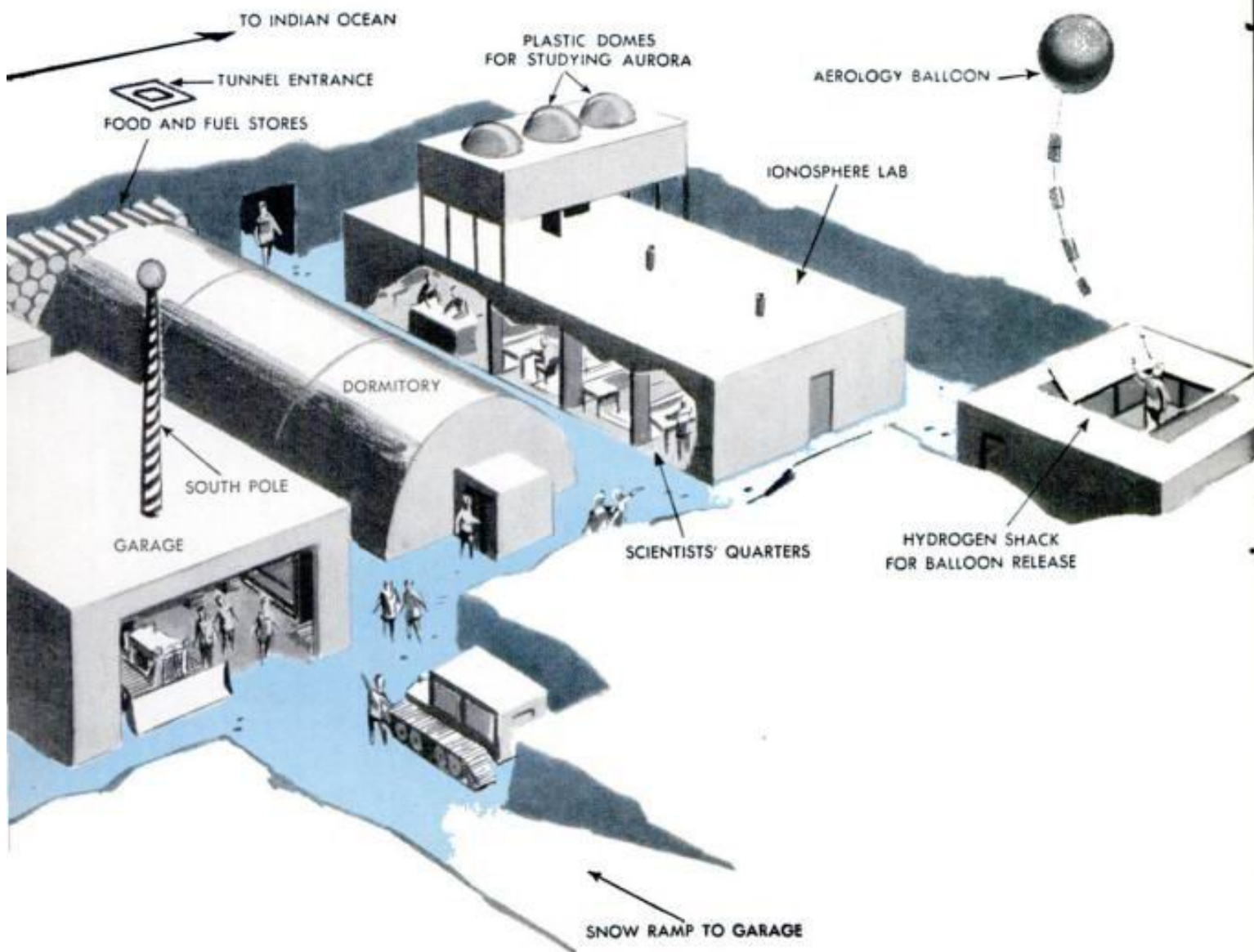
Navy Seabee at left is working on portable heater used to warm one of the Jamesway huts in which party lives. Drawing shows South Pole "community"



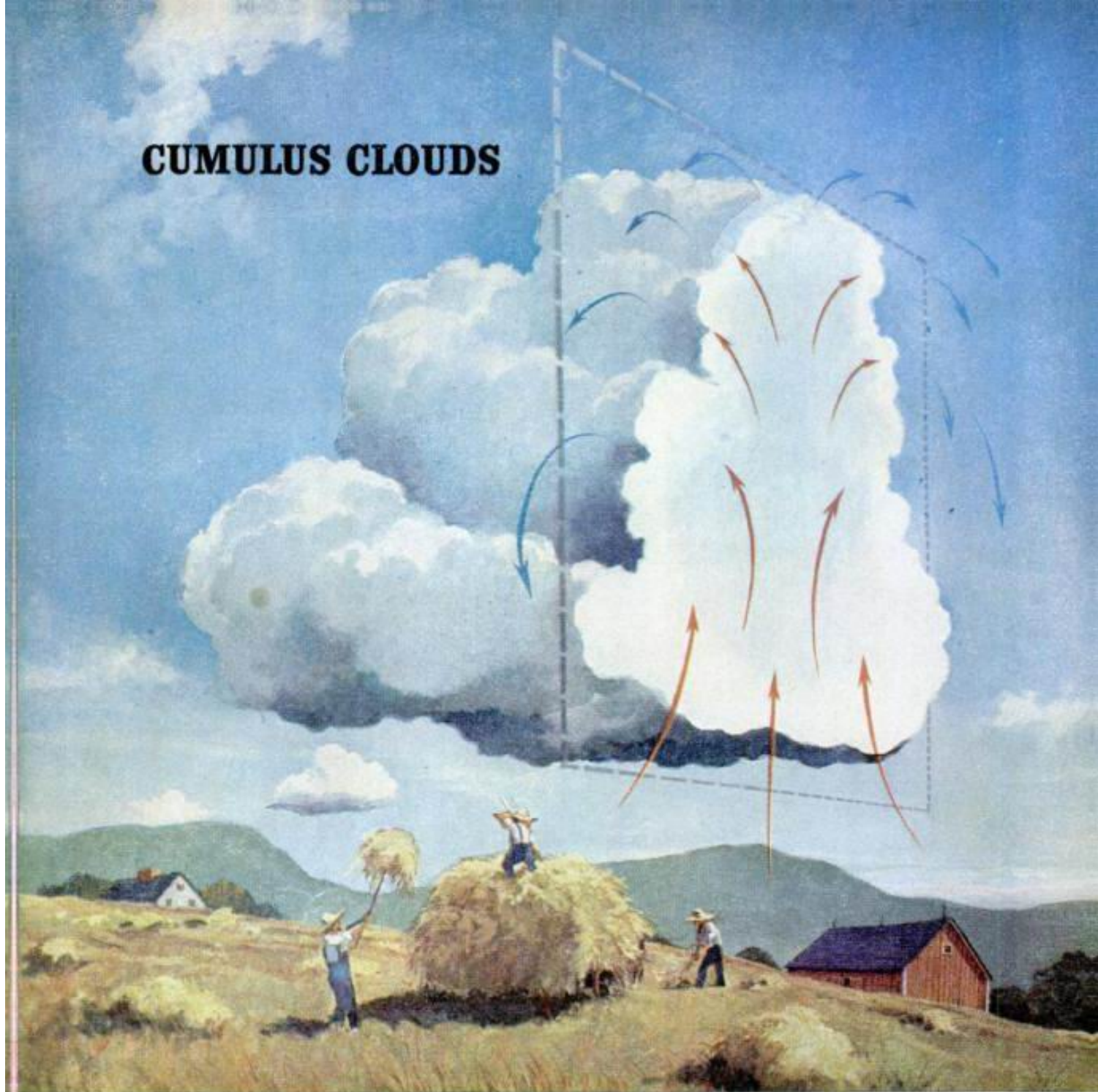
the surface when the planes sat still on it for a few minutes. Huge batteries of JATO bottles lashed to the fuselage were needed to blast them loose and up into the rarefied air. Weird Polar phenomena resulted from these take-offs. Long, white contrails of vapor streamed away behind the planes. These particles quickly froze into ice spicules, accumulating more vapor until, within five minutes after a take-off, billowing surface clouds would roll across the wastes, swallowing everything in a dense ice fog. In half an hour, the sky would be overcast from horizon to horizon, and a complete "whiteout" would have settled in—all from one plane. The sun, shining dimly through the blanket, gathered around it interlocking rings of refracted light, which Doctor Siple called "the five suns."



Navy radioman, above, works on the party's short-wave transmitter, their only link to outside world



CUMULUS CLOUDS



Cumulus clouds form when sun-warmed air cools. Coldness comes with altitude. Cooling shrinks (condenses the volume of) air, squeezing invisible moisture (vapor) into visible droplets (clouds). This miracle occurs at about 4000 feet.

If you wring out a wet towel, the drier the towel the more you have to squeeze to produce water. Likewise, the drier the air, the more height (chill) is needed to squeeze its vapor into a cloud. Above is a cross section through a cumulus. Red

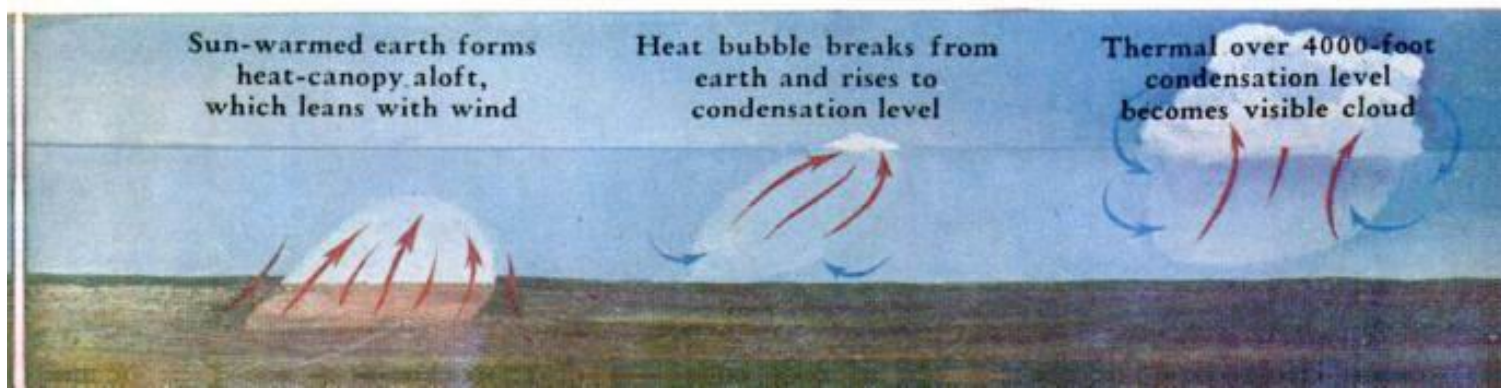
arrows show rising thermals (warm air). Blue arrows show falling currents of cooled air. This mechanical cell might last 20 minutes or so as the cloud builds up, then disintegrates back into the air. If the air is very wet and very warm, cumulus can grow into a thermal thunderstorm.

The drawings below show sequence of a cumulus, and why it is the visible upper part of a thermal cell. Any fine white cloud may have started as swamp water or moist dirt some 50 miles away!

Sun-warmed earth forms heat-canopy aloft, which leans with wind

Heat bubble breaks from earth and rises to condensation level

Thermal over 4000-foot condensation level becomes visible cloud





Above are two fields of cumulus clouds with different heights, shapes and colors. The clouds on the left are high, oval-shaped with flat bottoms. They indicate fair weather. The clouds on the right are chaotic and tufted, resembling shellbursts. They are lower and darker. This sky promises showers.

Darkness in clouds is no indication of rain if the clouds remain high. However, thunderstorms usually move from west to east, so darkness in the west is always a threat.



The most important thing in cloud watching is to note the direction of movement. If clouds are moving in prevailing-wind direction, fair weather is best assured.

Learn prevailing winds (usually west to northerly during winter, west to southerly during summer) and you can tell fair skies from threatening ones. Storms never come from wind direction because winds always pinwheel around low pressure; face wind and nearest storm center will be on right (opposite in southern hemisphere).

FRONTS

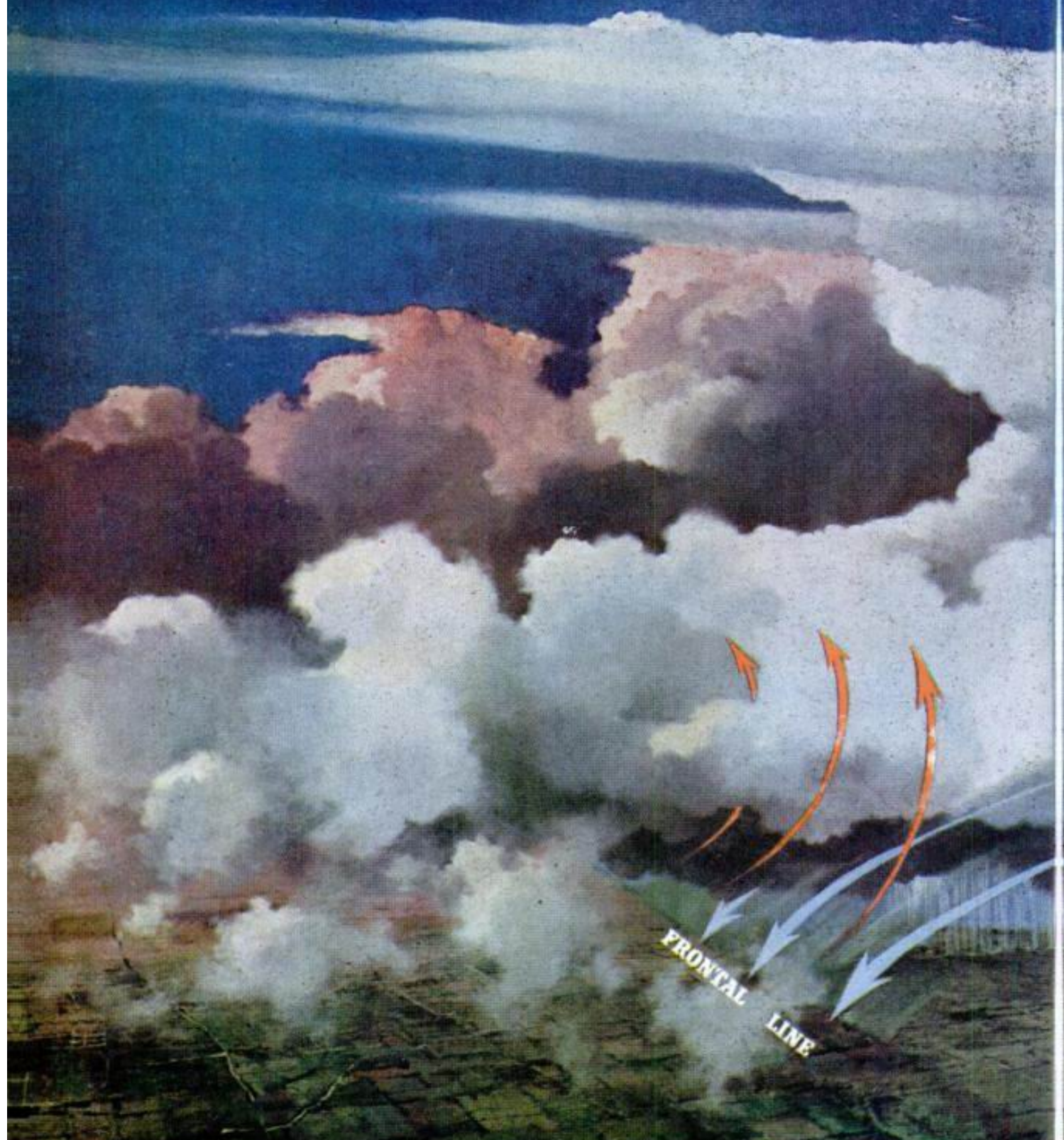
Weathermen look for rain along fronts. Fronts are merely the prows of moving air masses. Along these collision fronts storms most often occur. When weather is cool, a warm-air mass usually brings the next rain; when it is warm, a cold-air mass usually brings the next storm.

The next four pages show invading cold and

warm-air masses with their characteristic clouds. Cold air is heavy and noses downward, with its front slanting back; cold-air masses feature cumulus types, short hard rains and good visibility.

Warm air is light, slanting overhead for hours before its rain, which is slower and longer lasting; clouds are stratus, and visibility poor.

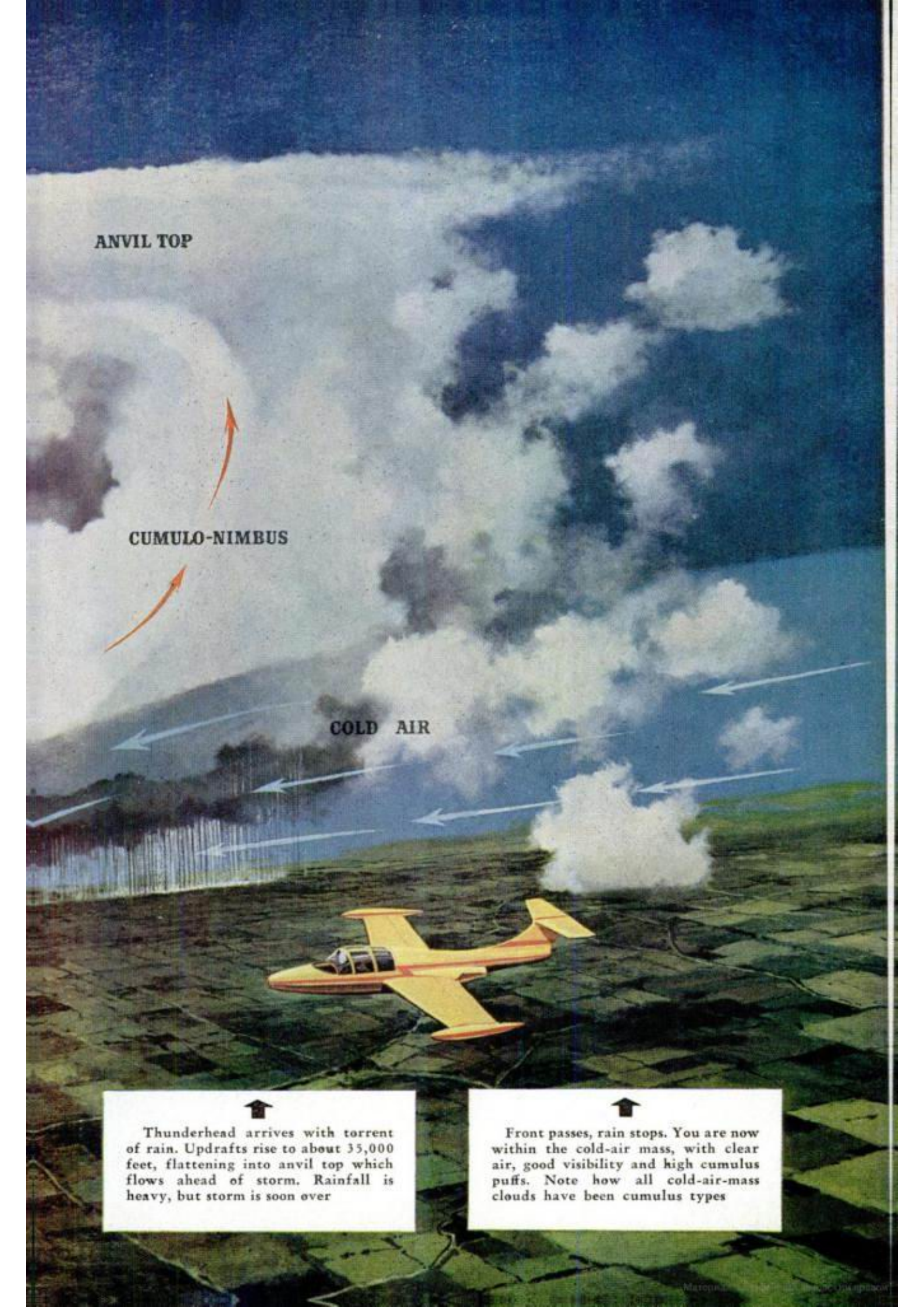
CLOUDS OF THE COLD-FRONT STORM



When warm-weather cumulus clouds darken and lower (usually from the west) and cobweb-ceiling (anvil top) flows overhead, a cold-air-mass storm is less than an hour away



Cold air (blue arrows) plows under warm air (red arrows) pushing it up into a boiling line of squall clouds. Rain is just ahead under approaching thunderhead (cumulo-nimbus)



ANVIL TOP

CUMULO-NIMBUS

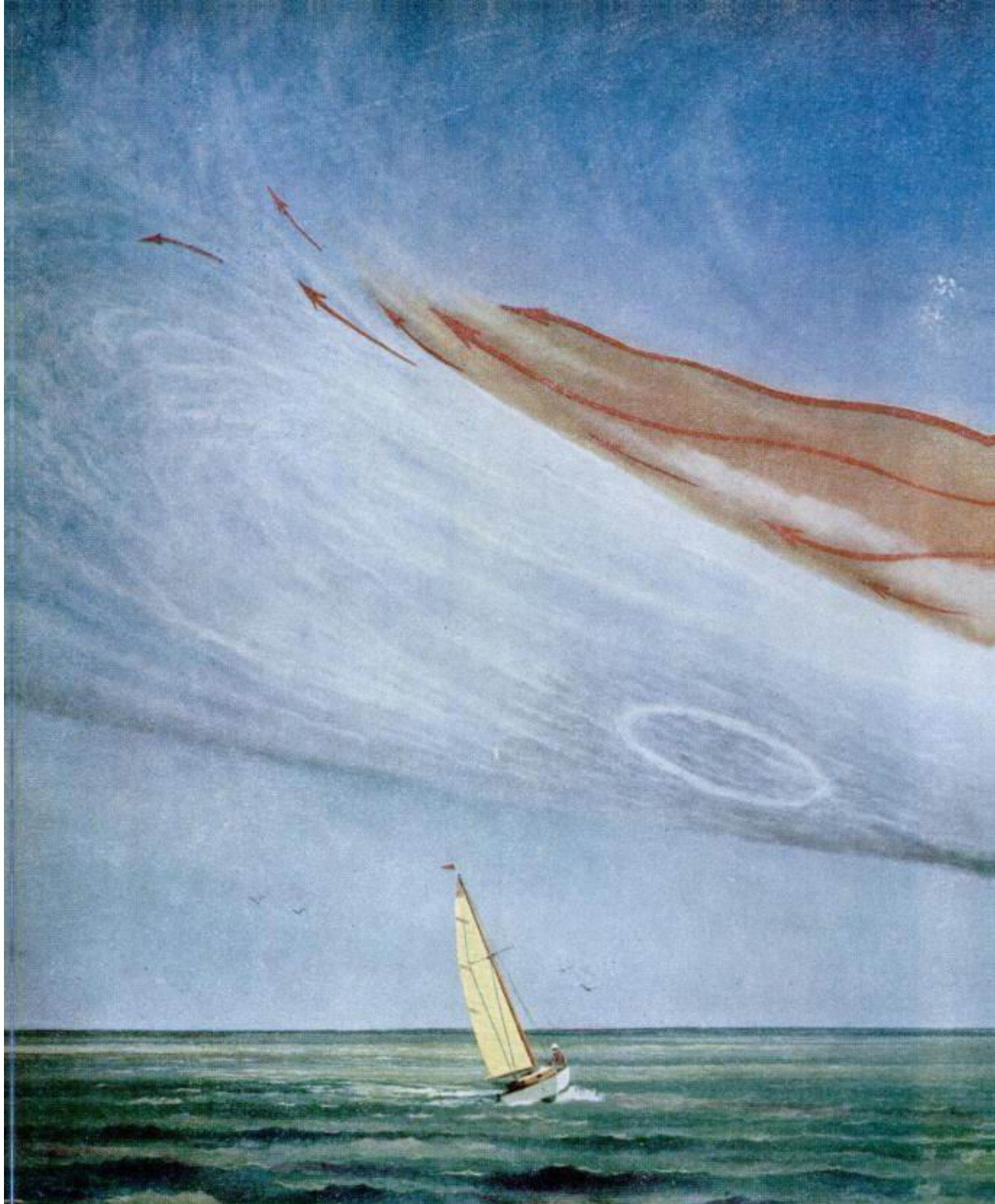
COLD AIR

↑

Thunderhead arrives with torrent of rain. Updrafts rise to about 35,000 feet, flattening into anvil top which flows ahead of storm. Rainfall is heavy, but storm is soon over

↑

Front passes, rain stops. You are now within the cold-air mass, with clear air, good visibility and high cumulus puffs. Note how all cold-air-mass clouds have been cumulus types



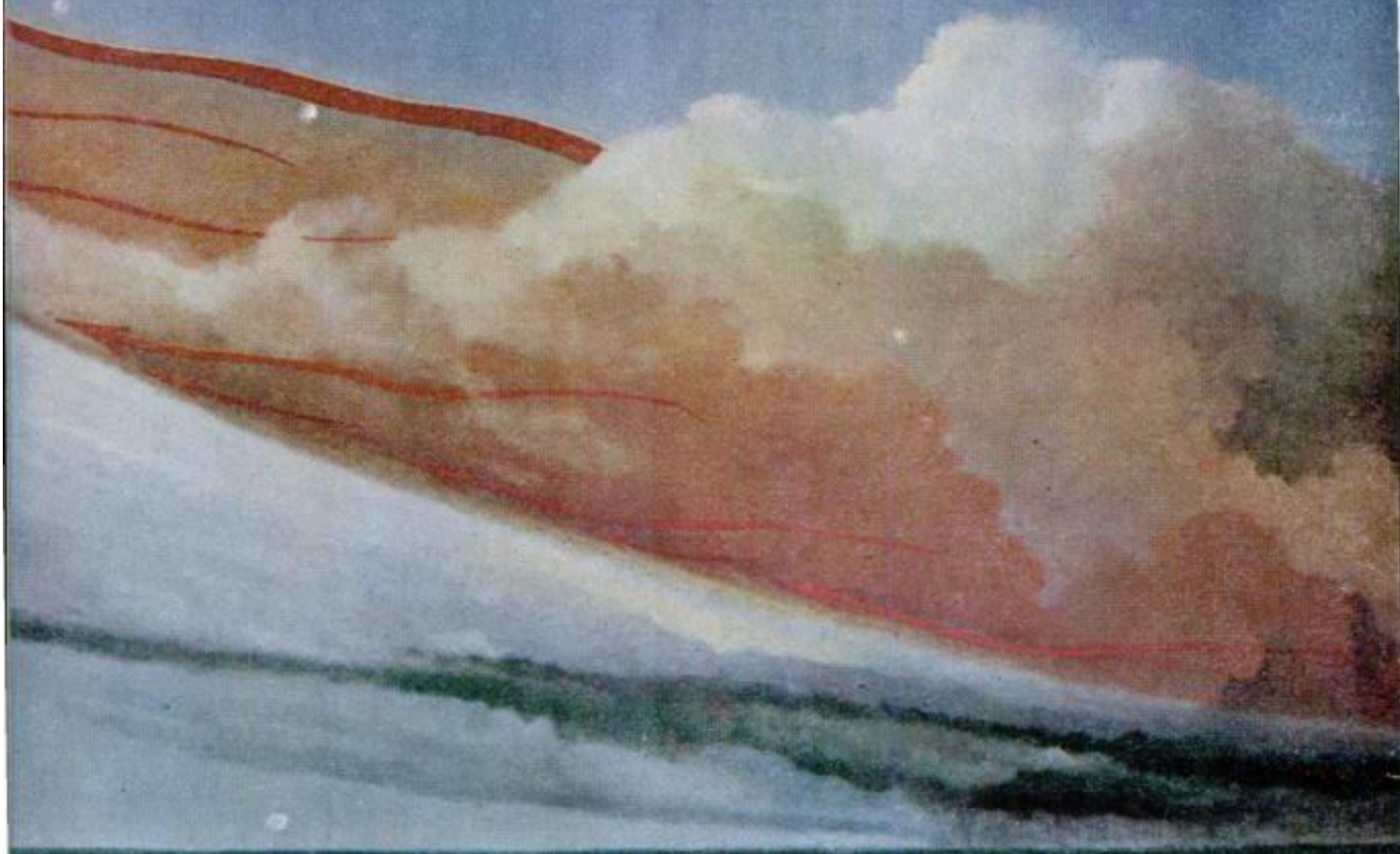
Nonprevailing wind, cirrus wisps (cobwebby ceiling) indicate tip of an approaching warm-air mass. Rain is about 800 miles away



Overcast thickens to foglike sheets (cirro-stratus). Sun or moon shines through, but a halo appears. Rain is imminent

CLOUDS OF THE WARM-FRONT STORM

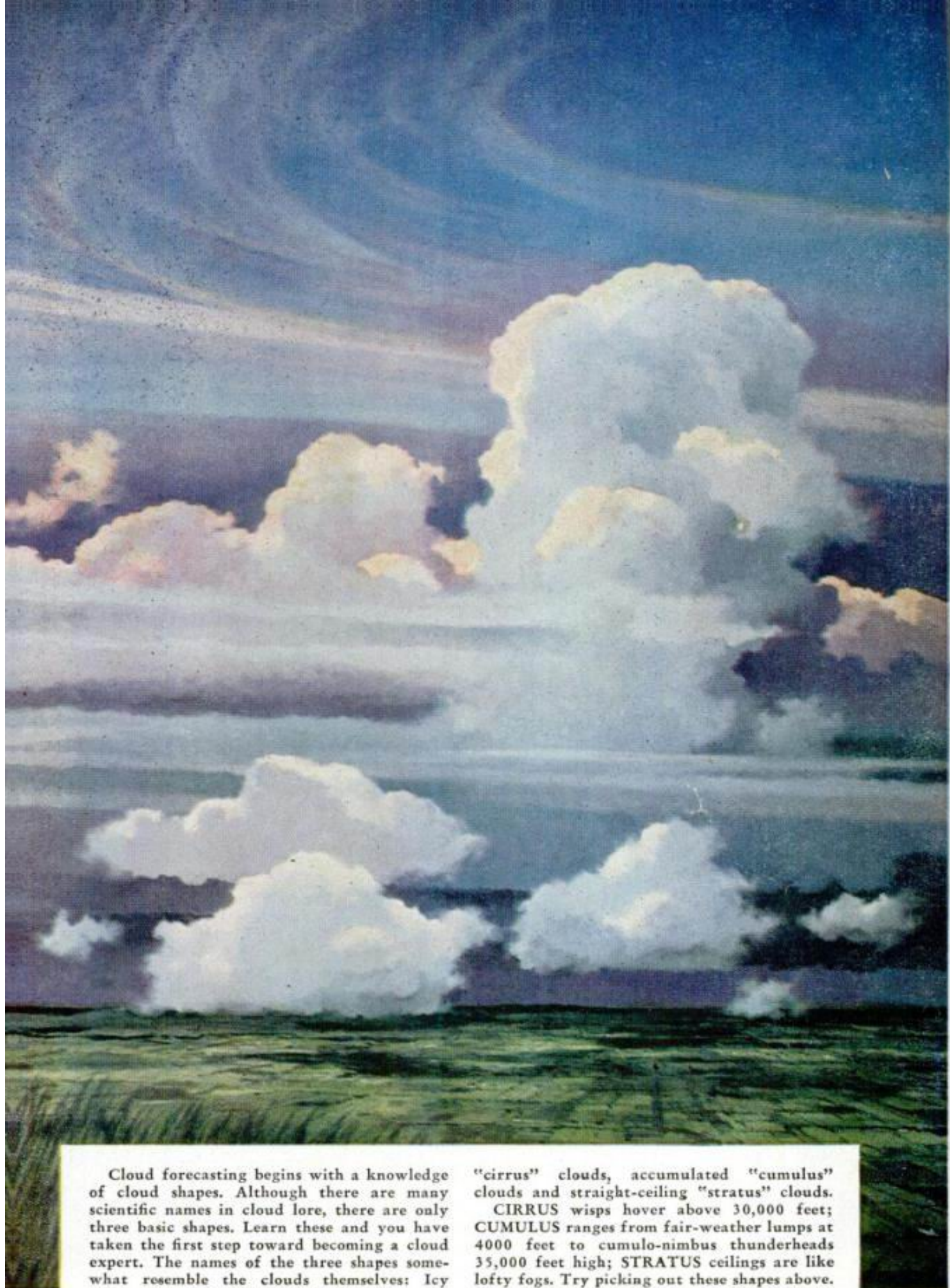
Although snowplow angle of the cold front gives little warning, warm air (red arrows) flows overhead from 10 to 40 hours before rain occurs. The sloping front may be 1000 miles long. Rain often lasts "as long as it took to come." The storm is usually sullen, less violent than a cold-front storm. Air in the wake is usually warm, hazy, moist and visibility is poor. Note the sequence of stratus-type clouds and the slant of warm air.



Ceiling lowers. The sun or moon becomes a shapeless "ground glass" glow and finally disappears. Alto-stratus clouds appear



Alto-stratus lowers to nimbo-stratus (shapeless rain masses). Precipitation is spotty, starting slowly and lasting a long time



Cloud forecasting begins with a knowledge of cloud shapes. Although there are many scientific names in cloud lore, there are only three basic shapes. Learn these and you have taken the first step toward becoming a cloud expert. The names of the three shapes somewhat resemble the clouds themselves: Icy

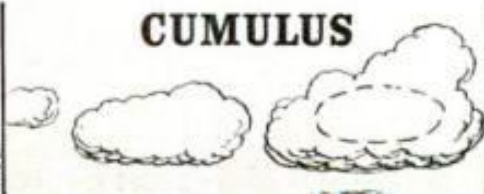
"cirrus" clouds, accumulated "cumulus" clouds and straight-ceiling "stratus" clouds.

CIRRUS wisps hover above 30,000 feet; CUMULUS ranges from fair-weather lumps at 4000 feet to cumulo-nimbus thunderheads 35,000 feet high; STRATUS ceilings are like lofty fogs. Try picking out these shapes above.

CIRRUS



CUMULUS



STRATUS



The outdoorsman who can't get weather reports must depend upon his own observations. There is a good deal of superstition about the weather, but some folklore has a sound scientific basis. Below are some of the superstitions with a

strong element of truth. Remember them and you will be better able to predict tomorrow's weather. They may also be useful in predicting the weather for a specific location when reports are general and uncertain.



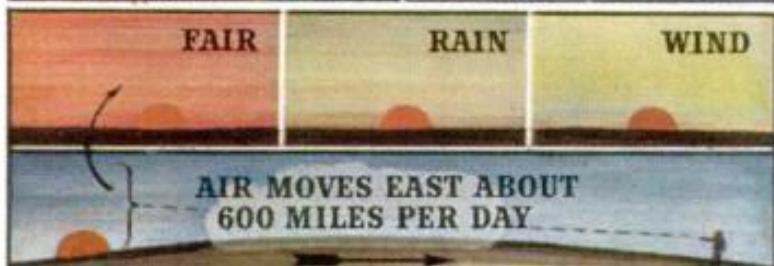
SOUNDS ARE HOLLOW BEFORE RAIN: Lowering clouds (A) make distant sounds (planes, trains, etc.) louder, with an echo effect

DISTANT SHORES SEEM NEAR BEFORE RAIN: Unstable air (B) removes salt haze, making the horizon clearer



NO DEW, SURE RAIN: Heaviest dew forms in cloudless air. Heavy dew, fair tomorrow

DULL MOON AND STARS FORETELL RAIN: High-altitude air inequalities cause moon and stars to appear fuzzy. Sharp moon and untwinkling stars foretell clear weather tomorrow



SUNSET COLORS FORETELL WEATHER: Moisture in western air (which will reach you tomorrow) tips off the weather. Red means fair; pale yellow-gray, rain; bright yellow, winds. Colors, remember, refer to the sky, not the actual sun

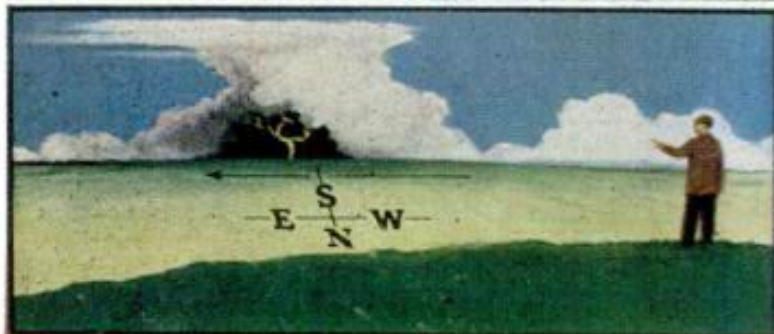


SUN AND MOON HALOS HINT RAIN: Halos occur in ice clouds of approaching warm-air rain

BIGGER THE HALO, NEARER THE RAIN: Lower clouds cause bigger halos, so rain is that much closer. Halo predictions are most accurate during warmer months



FACING WIND NEAREST STORM IS ON RIGHT: Counter-clockwise spin of low pressure makes this true in northern hemisphere. Just the opposite is true in southern hemisphere. This works with all low-pressure rains and will tell the location of a hurricane's eye and plot its movements



MOST THUNDERSTORMS MOVE EASTWARD: Lightning seen from anywhere but western sector of sky is from a storm which will pass you by. The anvil top of thunderheads flows in the direction of the storm

Gas Turbines Drive Torpedo Boats

Two vessels of the British Navy are among the first in the world to be powered by turbines burning gasified fuel oil. Fast and well-armed, they represent a new type of light warship. Unlike the *Grey Goose*, the *Bold Pioneer* supplements its turbines with a diesel cruising engine which drives a central propeller. Two Metro-Vickers gas turbines work through reduction gearing to drive twin reversible propellers. Armed with at least two torpedo tubes, a dual-purpose gun and a Bofors antiaircraft gun, the boat carries a crew of 18. Two Rolls-Royce gas turbines drive the twin reversible screws of the *Grey Goose*, a converted World War II gunboat. Multistage compression and a heat exchanger maintain high-compression ratio. Armed with a forward gun and torpedo tubes, it also mounts "Squid" launchers, weapons capable of pin-pointing depth charges far from the ship

BOLD PIONEER MOTOR TORPEDO BOAT

LENGTH 120 FEET
BEAM 25 FEET

FORWARD GUN

LATTICE
MAST

STARBOARD
GAS TURBINE

STARBOARD
21-INCH
TORPEDO TUBE

PORT METRO-VICKERS
MARINE GAS TURBINE

PORT 21-INCH
TORPEDO TUBE

PORT ROLLS-ROYCE
GAS-TURBINE
MARINE ENGINE

INTERCOOLER

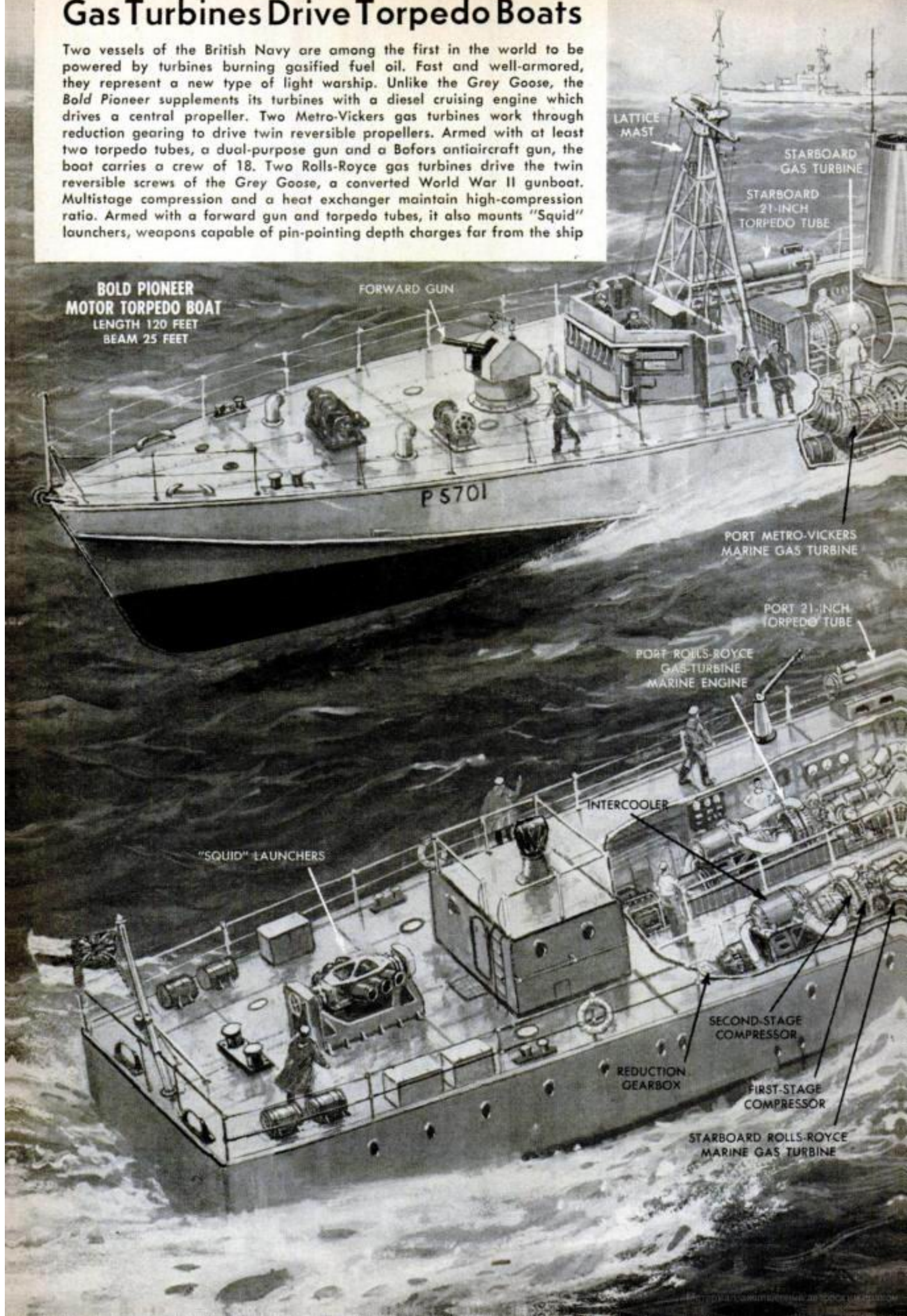
"SQUID" LAUNCHERS

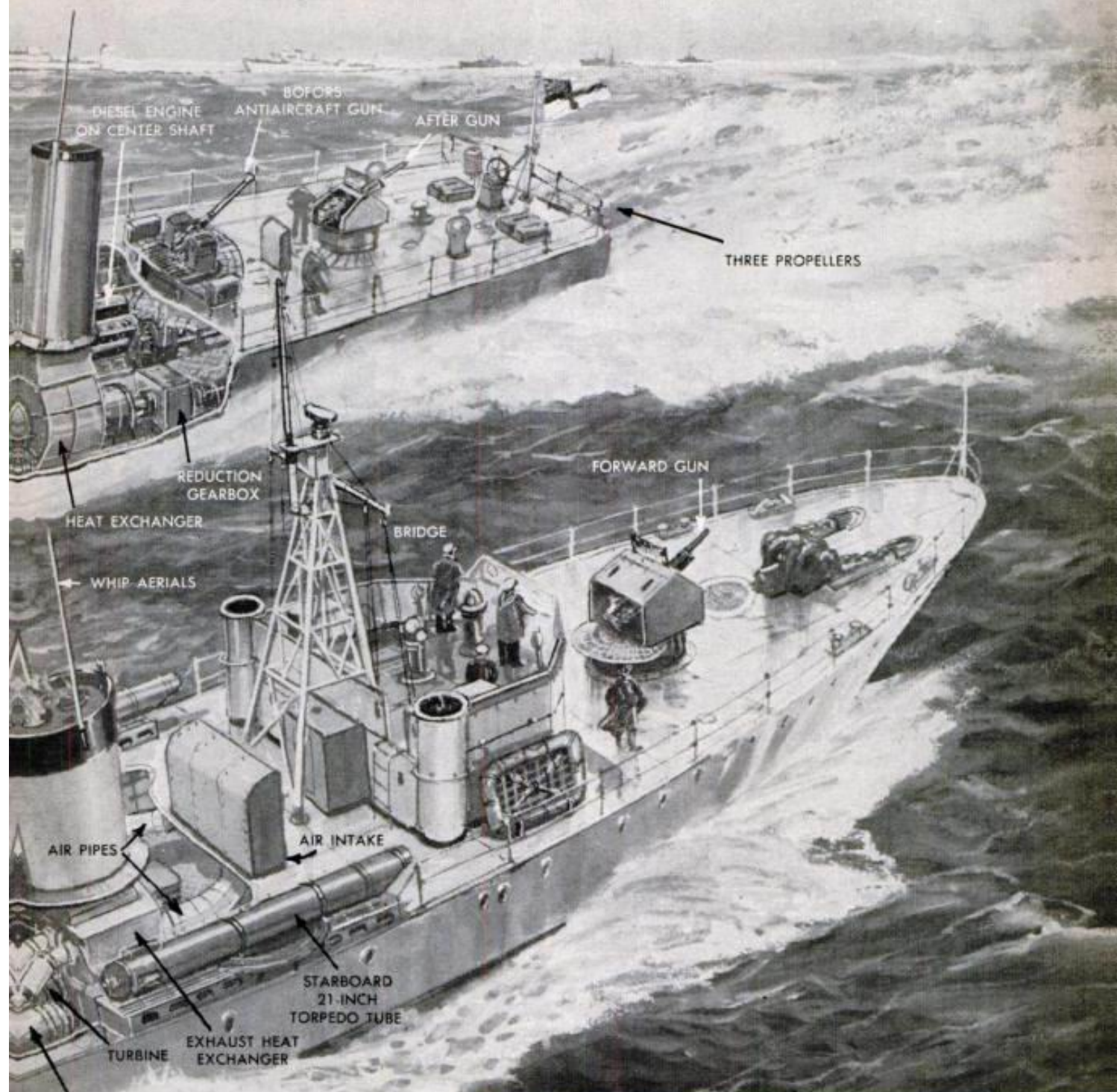
SECOND-STAGE
COMPRESSOR

REDUCTION
GEARBOX

FIRST-STAGE
COMPRESSOR

STARBOARD ROLLS-ROYCE
MARINE GAS TURBINE





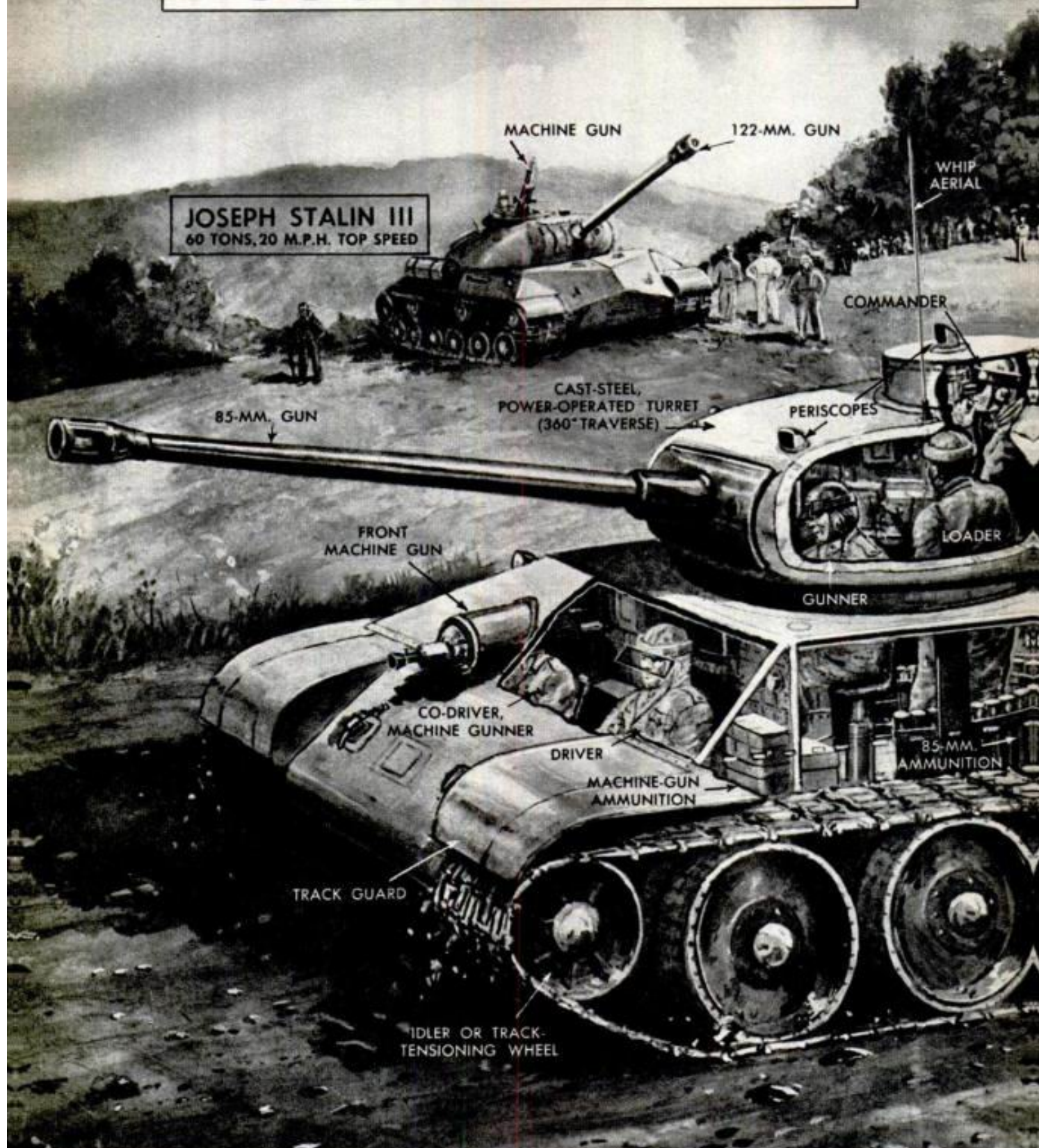
Bold Pioneer runs through tests. Speed of fast torpedo boat is secret

**GREY GOOSE
MOTOR TORPEDO GUNBOAT**

LENGTH 145 FEET
BEAM 20 FEET



RUSSIAN TANKS



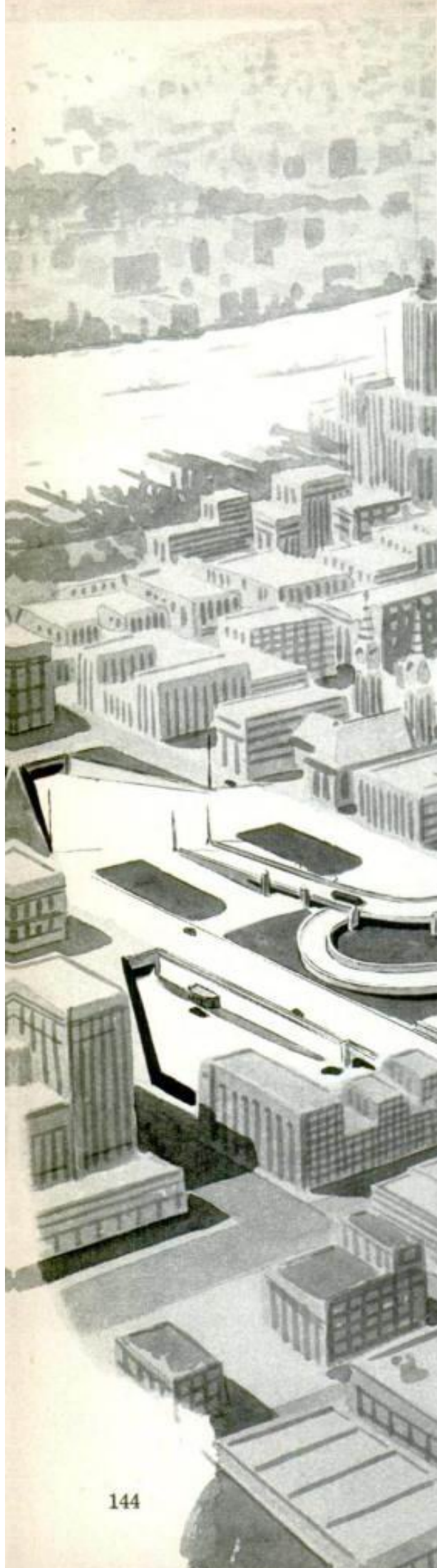
OUTSTANDING in number and effectiveness among the powerful ground armor used by North Korean forces in the opening phases of the Korean war was the Russian standard medium tank, the T-34, whose identity was fully authenticated by a number of captured examples. In the

foreground above and to the right are two illustrations of it, with one cut away to show the interior arrangement. The T-34 has been used by the Soviet army for nearly 10 years, with the most modern types radically improved by a different type turret, a heavier gun and carrying a crew of



five instead of four. It weighs about 34 tons and has a V-type 500-horsepower diesel engine that gives it a speed of 30 miles an hour. A heavier tank, not yet officially confirmed as the Joseph Stalin III, also was reported in the early action. Shown in the background above, the Stalin is the stand-

ard Russian heavy tank and an example of it crowns the Soviet war memorial in Berlin. It is described as one of the most powerful tanks in existence, weighing 60 tons—about 10 more than either the General Patton or the British Centurion—and mounting a long-barreled 122-mm. gun.

An aerial, sepia-toned photograph of a city. A wide river flows through the upper left portion of the image. The city is densely packed with buildings of various heights. In the lower right, a large, complex structure, possibly a transit terminal or industrial facility, is visible, featuring a prominent curved ramp or bridge. The overall scene depicts a bustling urban environment from a high vantage point.

the merry-go-round conveyor—an overhead chain almost a third of a mile long. At 16-foot intervals along the endless chain, metal fingers gape open. The conveyor has but one purpose—to haul the loaded platform trucks from one side of the big concrete slab to the other. To do this job, it moves them at the rapid rate of 148 feet per minute down the length of the platform, around the corner and down the other side. Each little truck has a tall mast on one end. When the workman has loaded the flat truck, he chalks its code number (received from the platform control room) on the truck's blackboard. Then he wheels it over to the belt conveyor, lining up the top of the mast with the open metal fingers. When the fingers strike the mast, they lock around it and the conveyor spins the shipment around the platform to the other side, where a designated workman recognizes the code number and unclips the truck. If he misses the first time, the truck will always be around again. The conveyor eliminates the need for pushing the trucks clear across the platform, and the endless confusion that might result if they were delivered by hand.

Meanwhile, paper work on Bill's truckload is fanning out through the building along the 6½ miles of pneumatic tubing. Carriers zoom through the tubes to each operating section and every important room in the terminal. Each destination has a code number.

Up in the routing section, one of the operators rifles the manifests which are to be sent down to the unloading berth. He glances at the huge blackboard

lining one wall and decides the proper route for one shipment. Slipping that manifest into a carrier, he turns a disk on the cylinder until it shows the proper code number, then inserts it into the tube. It is sucked immediately to the tube control room, where it is deposited on a moving belt, swung around and dumped in front of the router. He glances at the code number and inserts it into one of the 65 tubes for delivery to the truck bay.

One room in the vast building is lighted like a pinball machine. In the platform control section, big electronic panels with flashing code numbers show the movement of every item of freight in the terminal from a box of pins to a shipment of steel beams. Down on the platform, the worker turns a dial as he unloads or reloads each shipment. Numbers instantly pop up on the panel in the room, and the operator processes and sends out the papers covering that shipment.

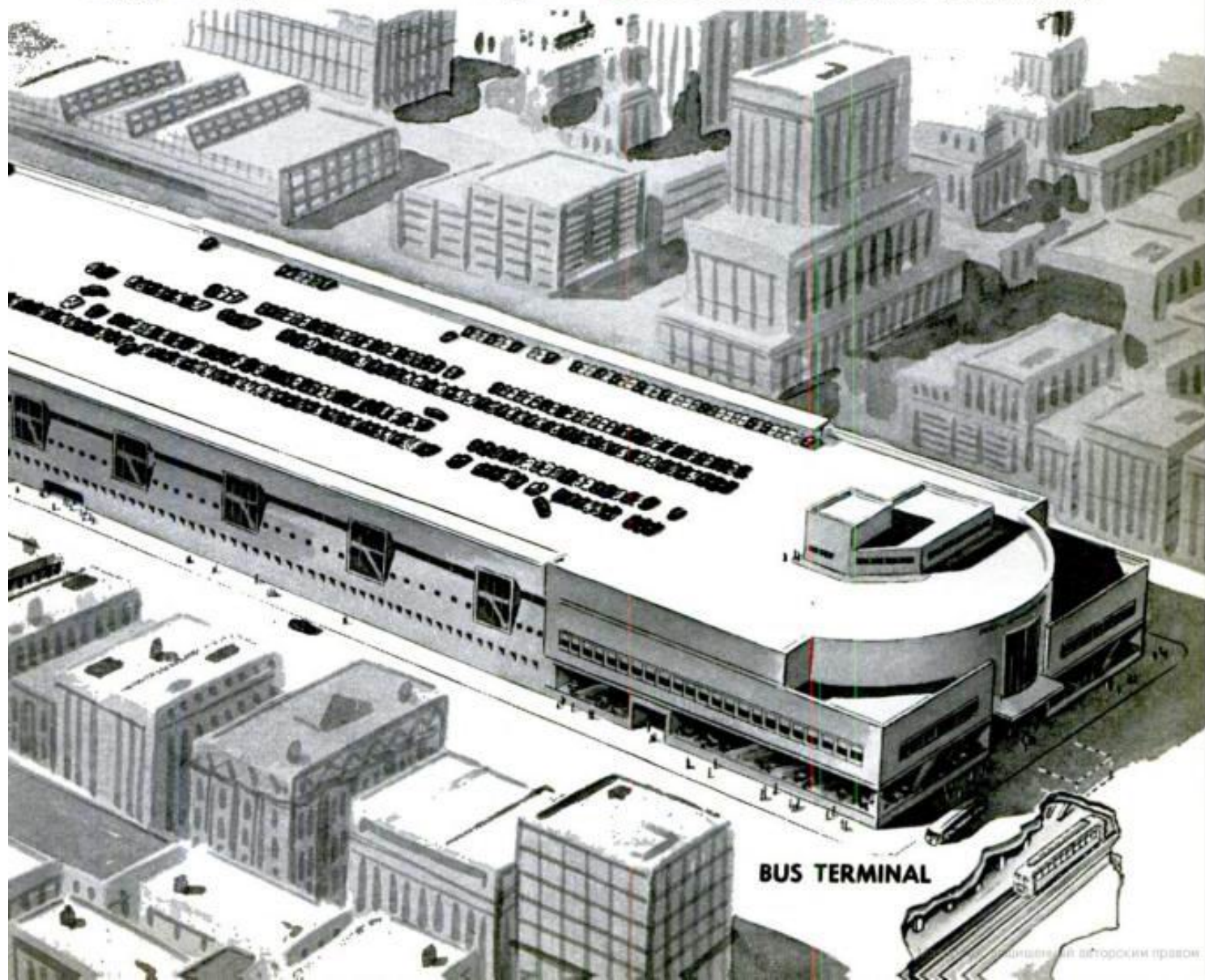
Each dispatcher has 20 telephone lines at his command for ordering deliveries and pickups. He prepares each load in street-address sequence, then sends out the mosquito-fleet trucks on their delivery runs. When a driver telephones that his truck is empty, the dispatcher routes him for pick-

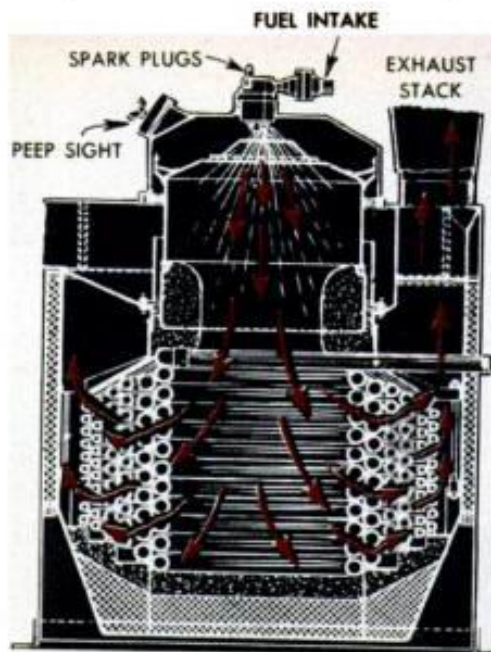
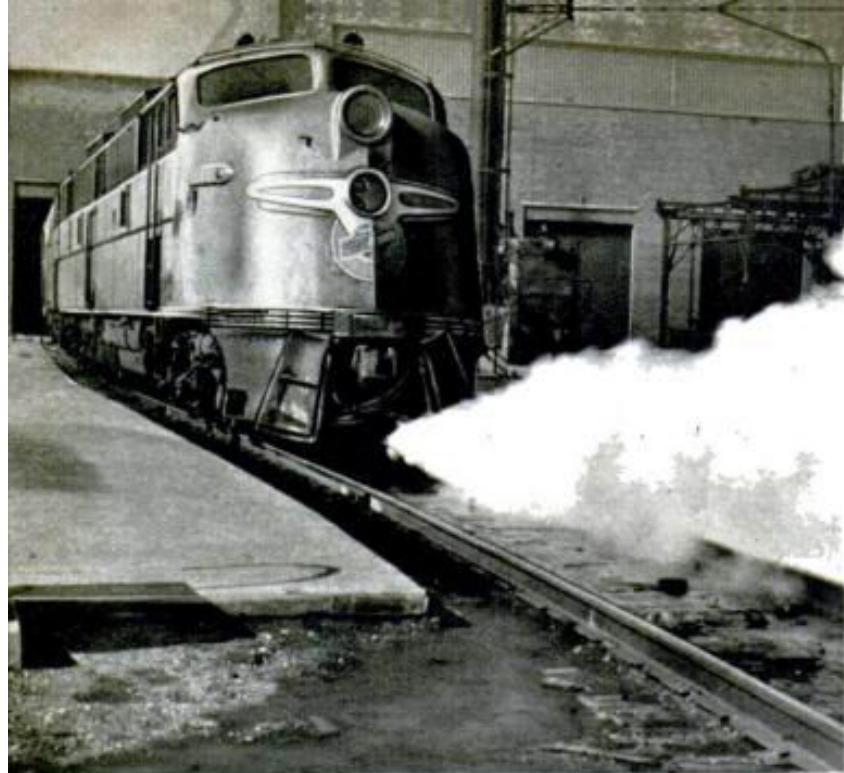
ups on his return trip to the terminal.

Just about every known device for jockeying freight from one point to another is built into the terminal. A cruising overhead crane zips tonnage shipments from one side of the platform to the other. Four big scales, including a 10-ton job, are spotted along the platform. In the recoopering shop, complete power equipment turns out new crates to replace those that have burst their seams. There are an in-bond room, short-term storage room and a special room for the storage of valuable merchandise. Automatic sorting machines and punch cards keep the paper work flowing. Topside, on the roof of the terminal, there are two fire stations and parking berths for 115 trucks. And spotted through the structure are banking facilities, a doctor's office and various conference rooms.

Across the river, in Newark, N. J., a twin terminal has been completed. Similar in
(Continued to page 240)

Buses will roll into new bus terminal every five seconds during peak periods. Located near Times Square, terminal will handle 130,000 passenger movements each day. Four-level building accommodates both suburban and highway busses. Ramps are radiant-heated to melt snow as it falls. Arrows show traffic patterns busses will use to and from Lincoln tunnel





Left, steam from a diesel! Its generator could heat nearly 100 homes. Right, firebox of a steam generator

IT TAKES A LOT OF STEAM TO RUN A DIESEL!

DIESELS may be pushing the steam locomotive into retirement, but they're doing it with an assist from the old champ. Without steam, the streamlined diesel passenger train would be as unpopular as an open-air taxicab in a heavy rain.

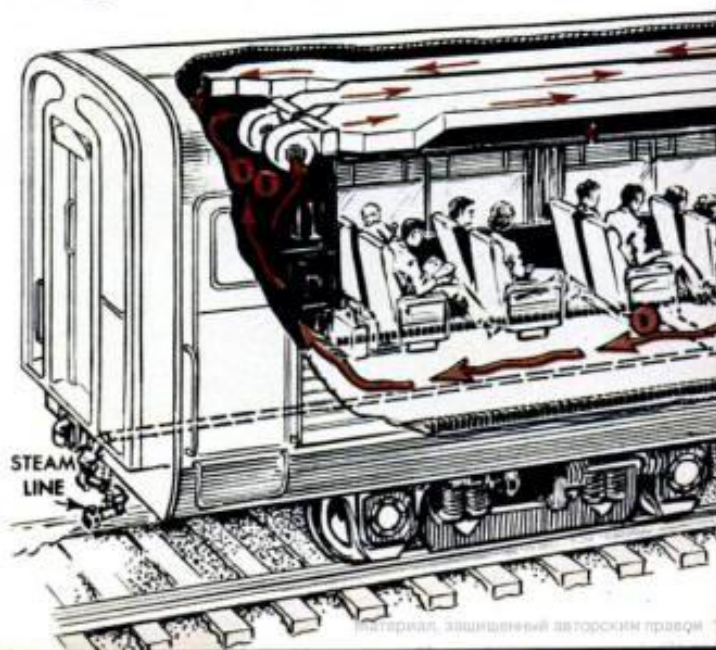
Without steam — lots of it — the streamliner would be cold in winter and hot in summer. It's steam that keeps today's train comfortable regardless of the weather. Tucked away in a corner of the diesel locomotive, where not even the most curious passenger can see it, is a compact steam generator. No bigger than the furnace in your home, it produces enough steam to heat 96 five-room houses in zero weather! It takes that much steam to keep a long train comfortable as it speeds across the country. This quick-acting generator, the unsung hero of the diesel revolution, reaches its full operating capacity in two minutes from a cold start. Try that trick on your furnace some time.

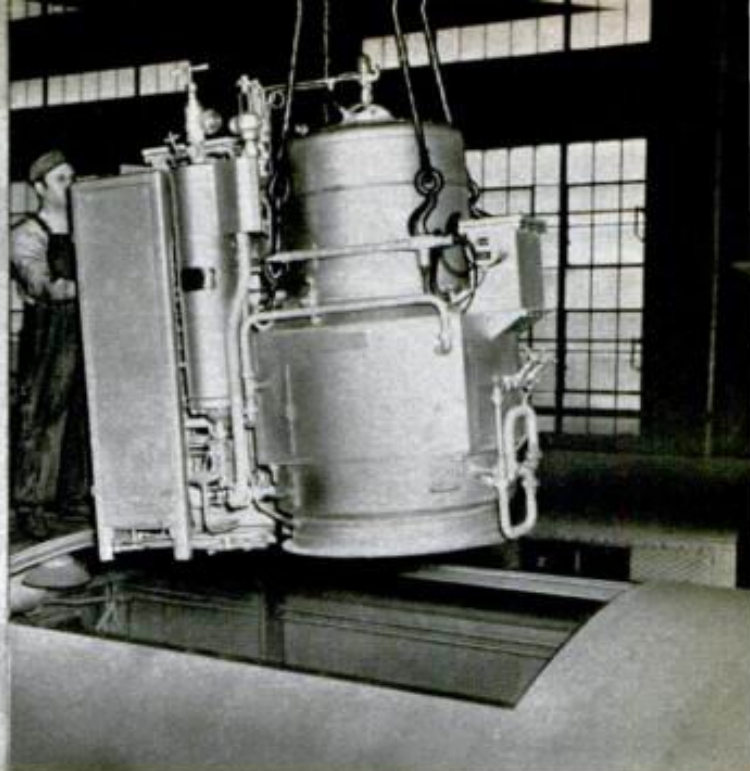
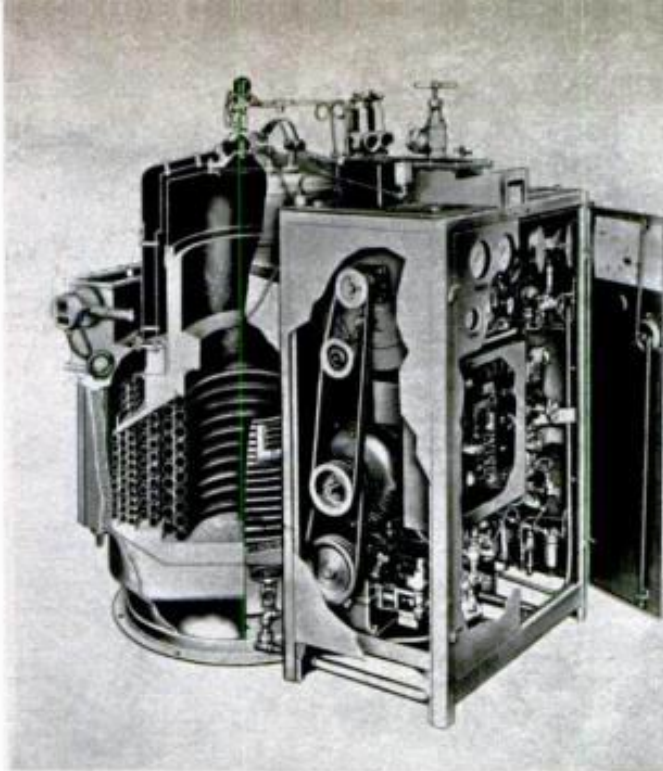
Train heating is so complicated that it makes the heating problem in a home look like child's play. Speeding over shiny rails, the streamliner is buffeted by a 90-mile-an-

hour gale. When the train stops, the wind dies down. The heating system has to respond instantly to prevent overheating. A few minutes later, the train is again zooming along at cannon-ball speed and the heater pours in the BTUs to replace the tremendous heat loss that is unavoidable at such speeds.

On compartment trains, the heating problem is complicated by a score or more passenger tastes. Obviously, what is hot enough for the thick-blooded outdoorsman in Roomette 4 is downright chilly to the sun-tanned blonde in Roomette 8, just returning from two months on Florida's

There are 12 thermostats in this dome car. Can you spot them? In addition, two solar disks in windows prevent overheating on the sunny side. Radiator is a pipe-within-a-pipe. Condensate runs off outer pipe





Vapor Heating Corp. photos

Left, cutaway shows complex control mechanism of heater. Right, lowering unit into rear end of a locomotive

beaches. There are as many tastes in heating as there are passengers and the system has to satisfy everybody. Individual thermostats and radiators in each compartment do the job. Passengers select their own temperatures and get tailor-made heat simply by turning a dial.

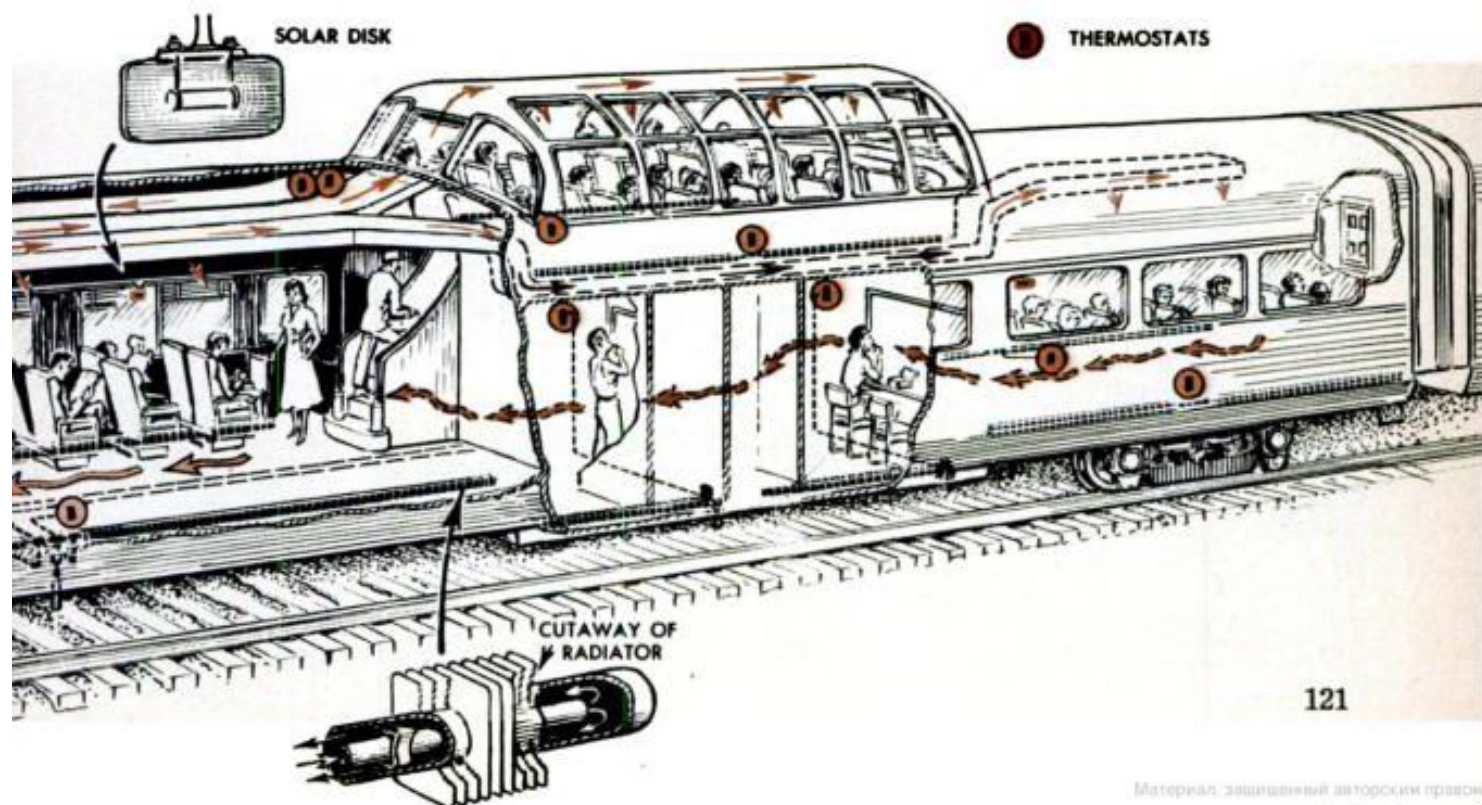
Railroads have discovered that men prefer their lounges a few degrees cooler than the rest of the coach. Women, on the other hand, want theirs a little warmer. So that's the way the lounge rooms are heated—sensitive thermostats take care of that.

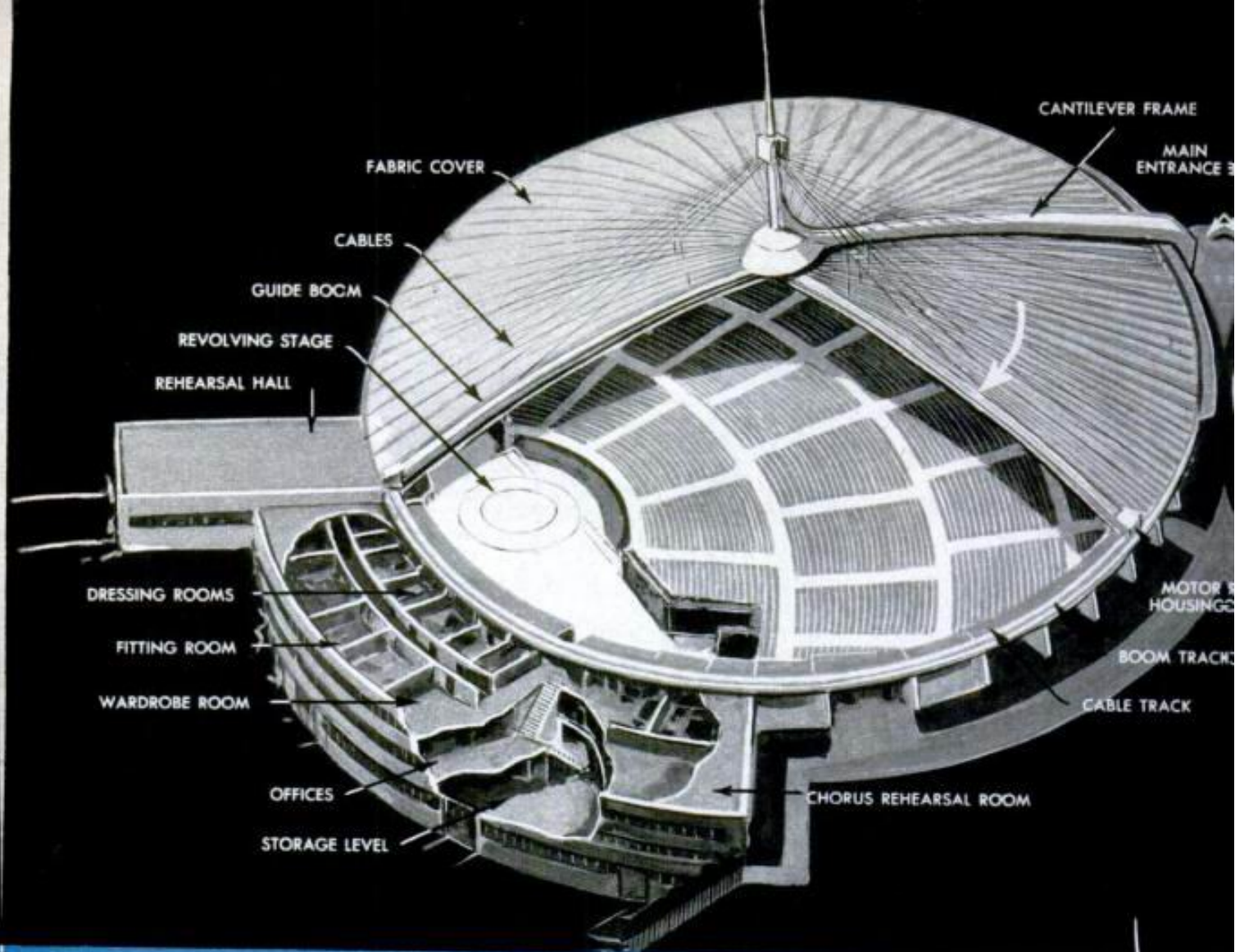
Passengers on the sunny side require less heat than those in the other half of the coach. To keep the sunny-siders from being too warm, there is a tricky device called

a solar disk that compensates for the sun's radiant heat. These disks are mounted on a window, one on each side of the coach. When the sun shines on them, they cut down the heat that goes into the radiators. These brand-new heat "detectives" work overtime in dome cars. Without them, you would roast when the sun was shining or freeze when it went behind a cloud.

Unlike your house, trains never stay in one climate very long. Today, they may be in the frigid North and tomorrow in the sunny South. The heating system doesn't care. It's prepared for anything. When the weather gets warm enough, the boiler automatically operates the air-conditioning

(Continued to page 234)

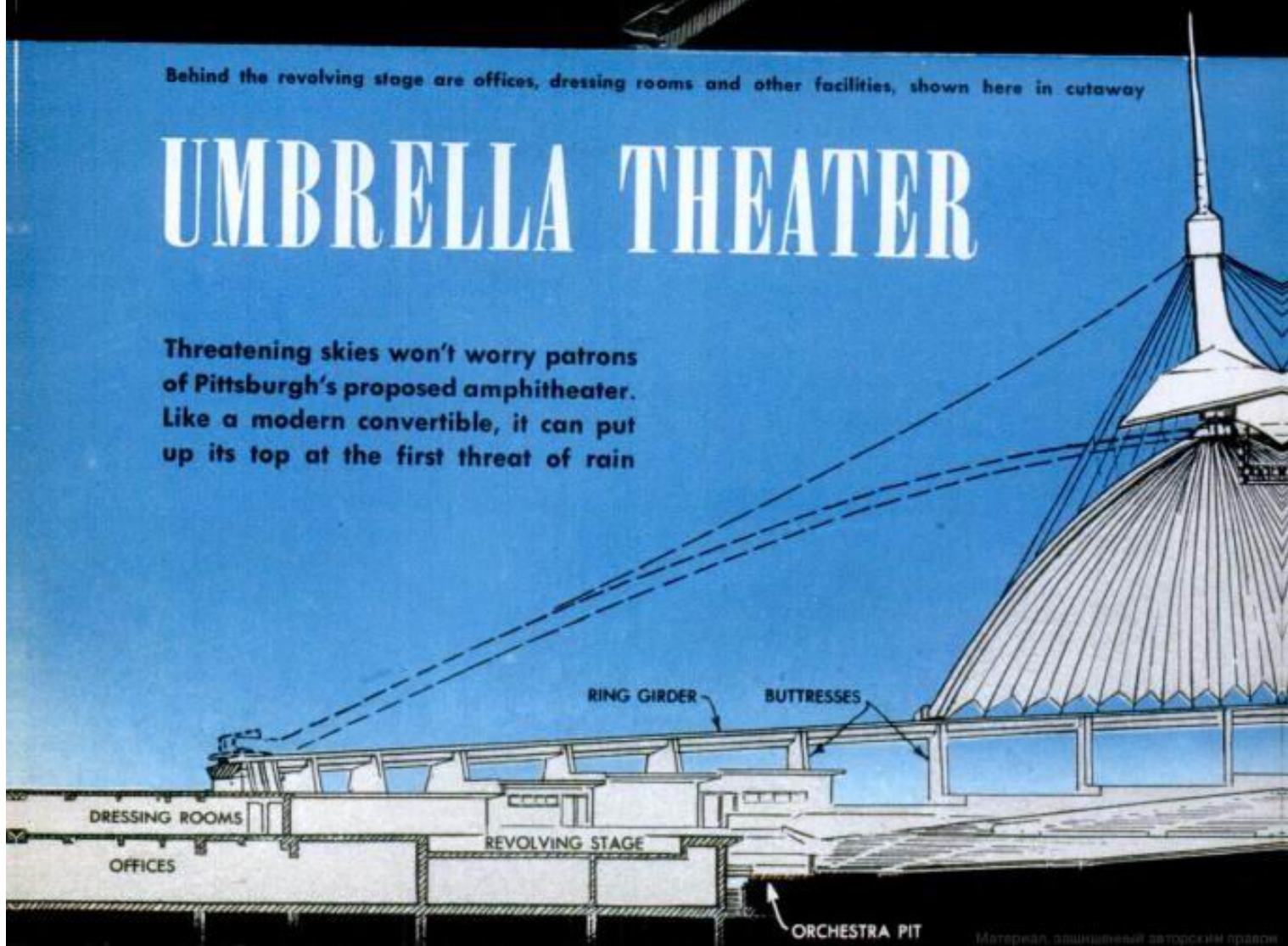


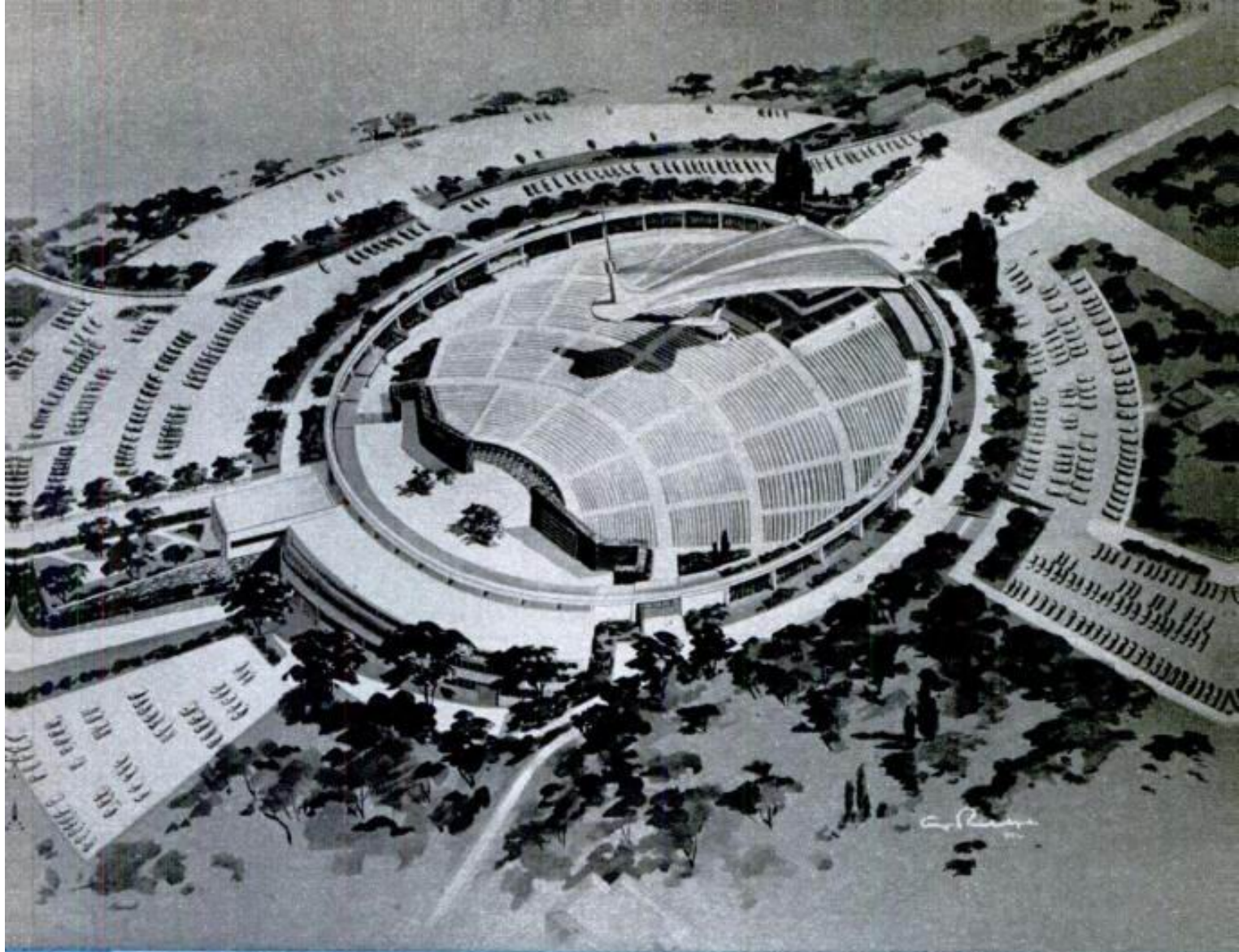


Behind the revolving stage are offices, dressing rooms and other facilities, shown here in cutaway

UMBRELLA THEATER

Threatening skies won't worry patrons of Pittsburgh's proposed amphitheater. Like a modern convertible, it can put up its top at the first threat of rain





Above drawing from Mitchell & Ritchey, Pittsburgh

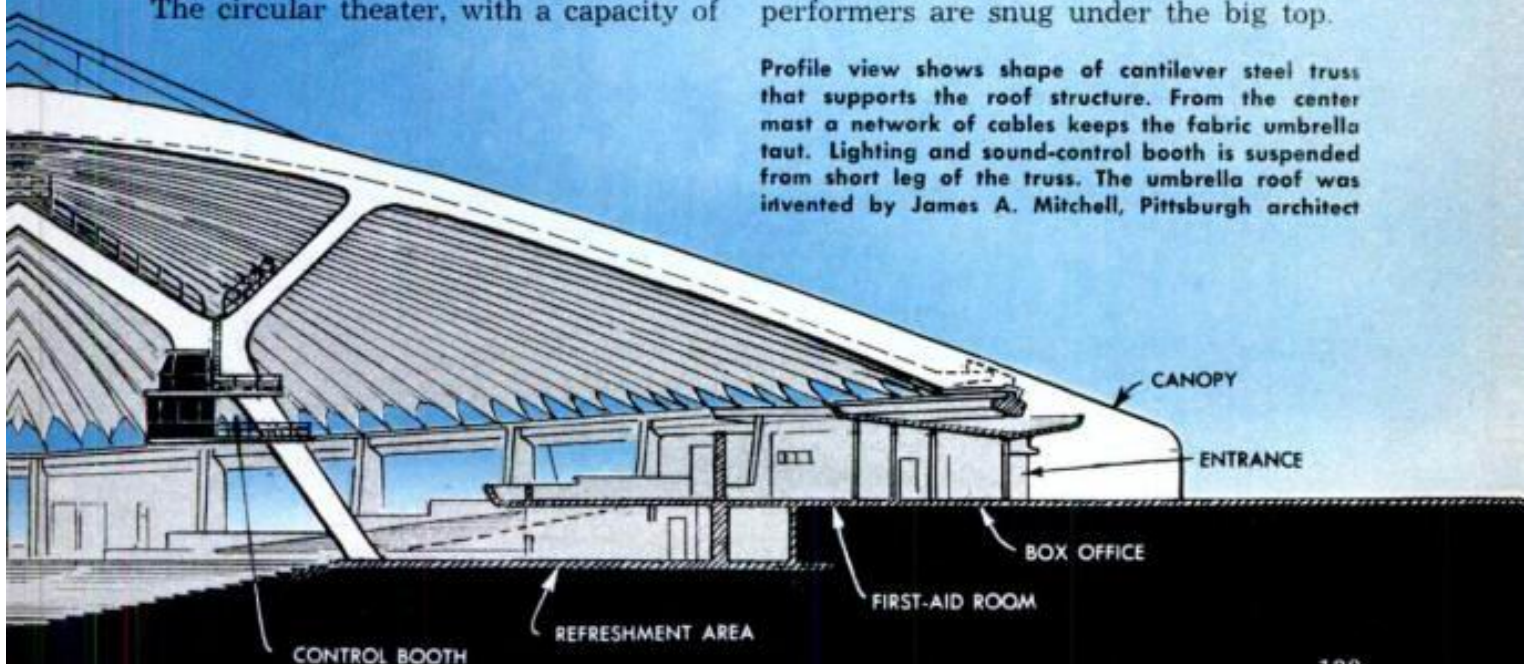
On clear nights, the fabric roof is furled neatly under the cantilever truss, providing starlit performances

RAIN and outdoor concerts just don't mix! Even dyed-in-the-wool fans admit that. So, when Pittsburgh decided to build an outdoor theater for its summer series of light opera, the architects borrowed a page from the car-manufacturers' book and designed a convertible theater.

The circular theater, with a capacity of

9000, will be roofless on clear nights, providing the thrill of performances under the stars. But should a rain-laden cloud show up, the manager touches a button and two electric motors "walk" around the perimeter track, unfolding a giant fabric umbrella. In 2½ minutes, the audience and performers are snug under the big top.

Profile view shows shape of cantilever steel truss that supports the roof structure. From the center mast a network of cables keeps the fabric umbrella taut. Lighting and sound-control booth is suspended from short leg of the truss. The umbrella roof was invented by James A. Mitchell, Pittsburgh architect

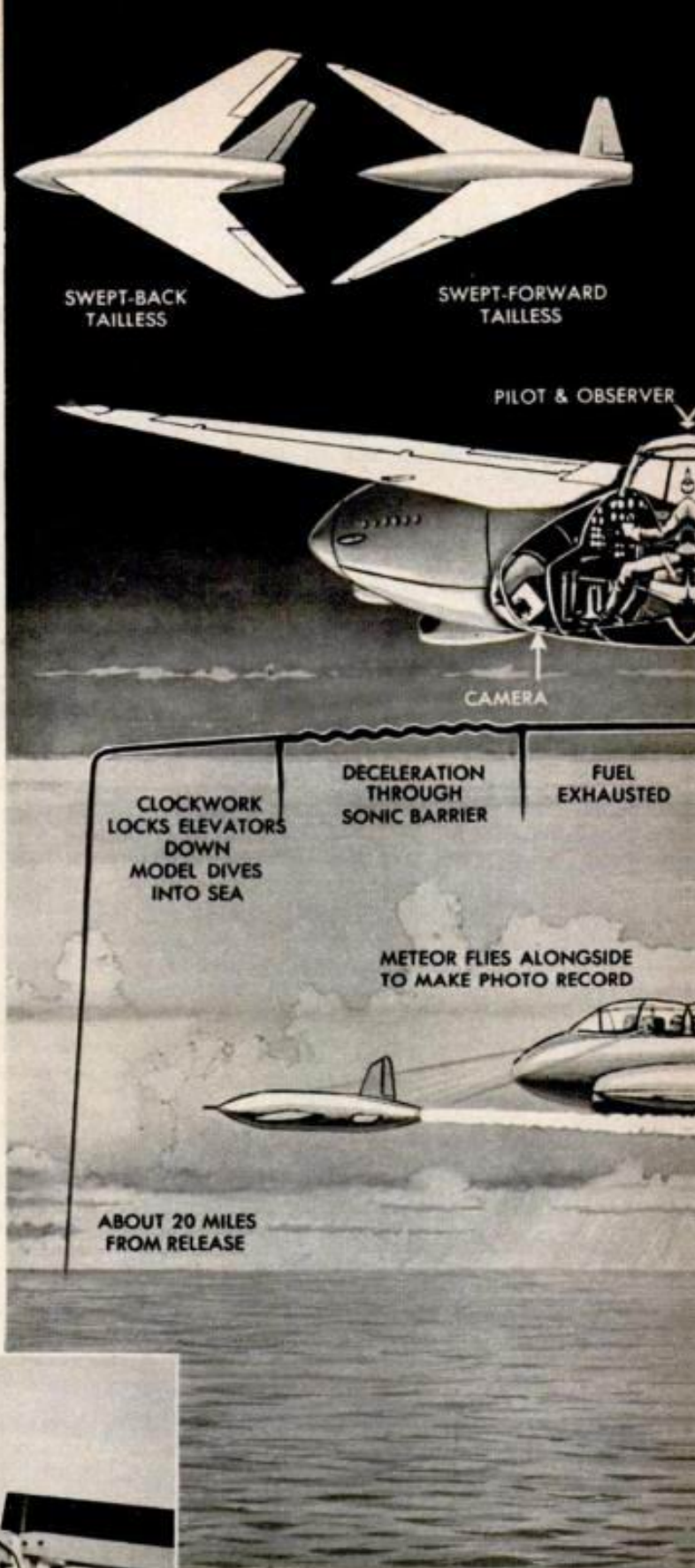


Robot Rockets Challenge Sonic Barrier

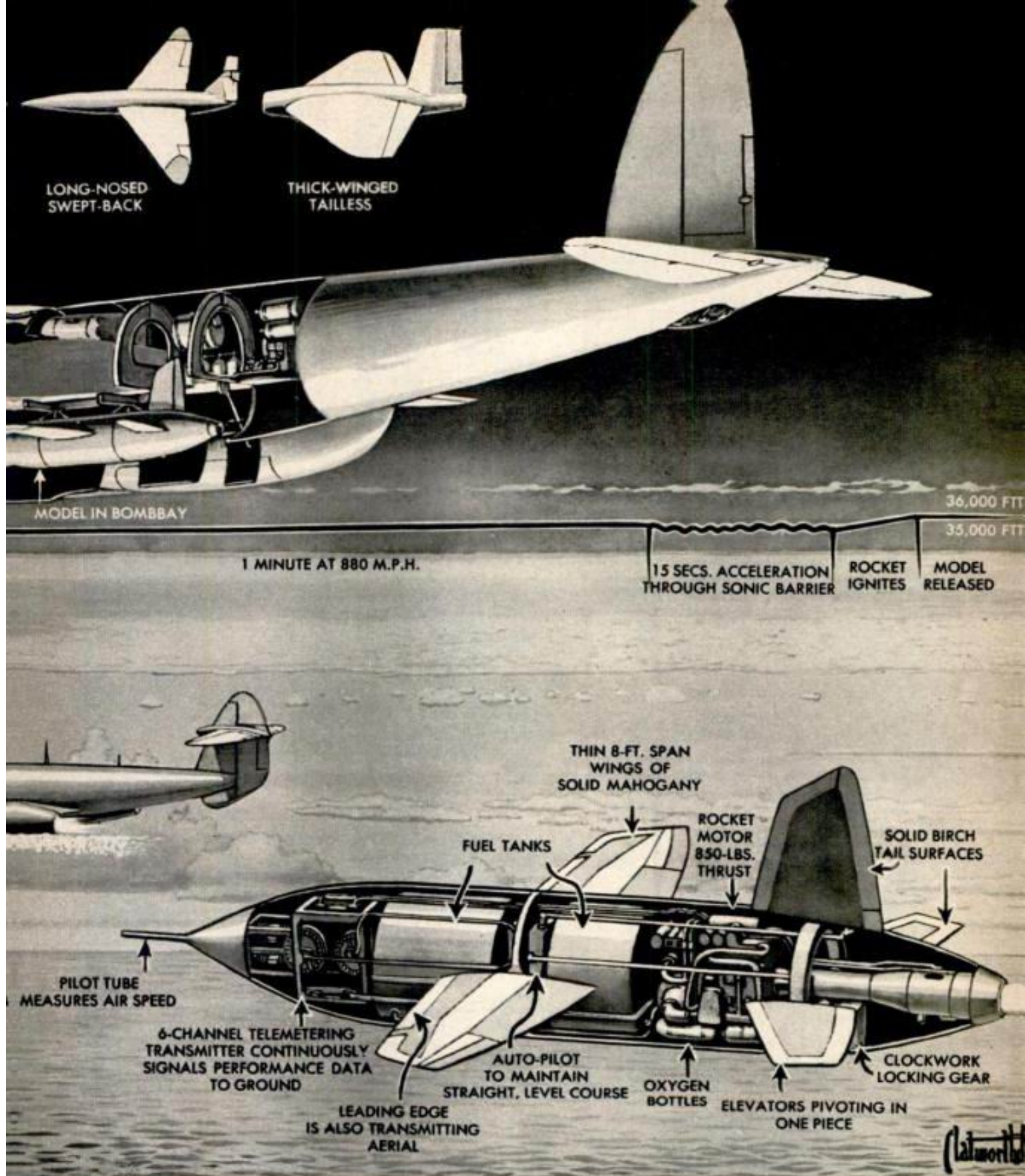
WHAT WILL HAPPEN when planes speed up and slow down on their way through the sonic barrier? To find the answers to one of the most critical problems of supersonic flight, Great Britain has started a six months' test program 14 miles off the Cornish coast. Most authorities are already agreed that aircraft will fly faster than sound successfully, once past the barrier.

Some 80 pilotless rocket models will be flown to probable destruction during the experiments, after brief bursts of blazing speed. They are being launched from beneath bombers flying about 400 miles an hour at 36,000 feet, gliding 15 seconds and losing about 1000 feet before their motors start. After one or two minutes level flying guided by an automatic pilot, the models crash into the sea to avoid danger to shipping.

During the run, batteries of automatic cameras in jet fighters patrolling the course shoot complete records of the test. In addition, each model carries a six-channel telemetering outfit that continuously radioes reports to the ground, where the flight is tracked on radar screens.



Cutaway diagrams, above, illustrate how the British experiments will be conducted. Speedy Mosquitoes will probably be used for the dropping assignments and 600-mile-an-hour jet Meteors for patrol duties. At the lower right is a typical rocket plane model. Left, in a U. S. test with supersonic projectiles, Navy technician adjusts fuses in rocket chambers of ramjet. One fired at Ft. Miles, Del., reached 1400 miles an hour



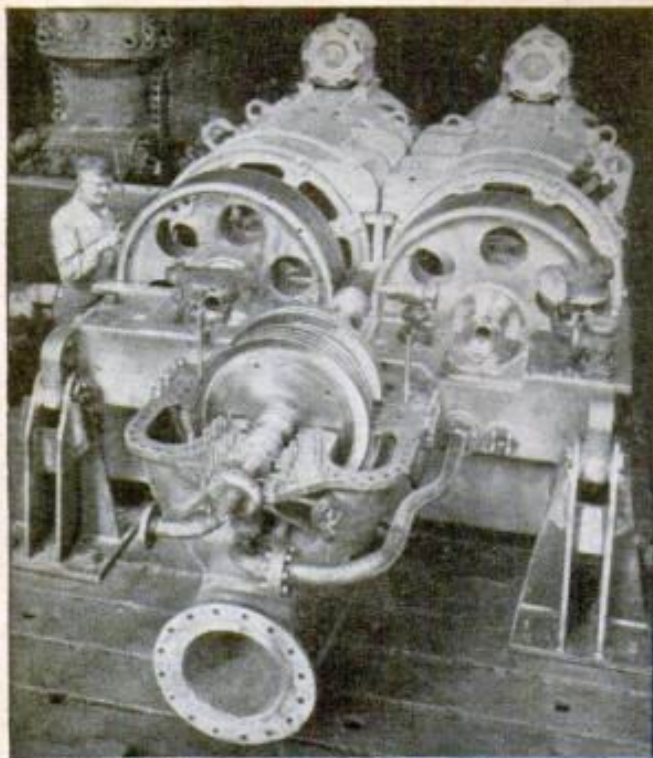
Copyright by S. W. Clatworthy

The test planes are built to scale. One of the first flown weighed approximately 900 pounds, had a highly polished mahogany skin and a 2000-horsepower alcohol-burning motor. It was close to 12 feet long and had an eight-foot wing span.

Models were decided on, instead of full-size planes, for the experiments because they are quicker and easier to build, permit quicker analysis of results, are simpler

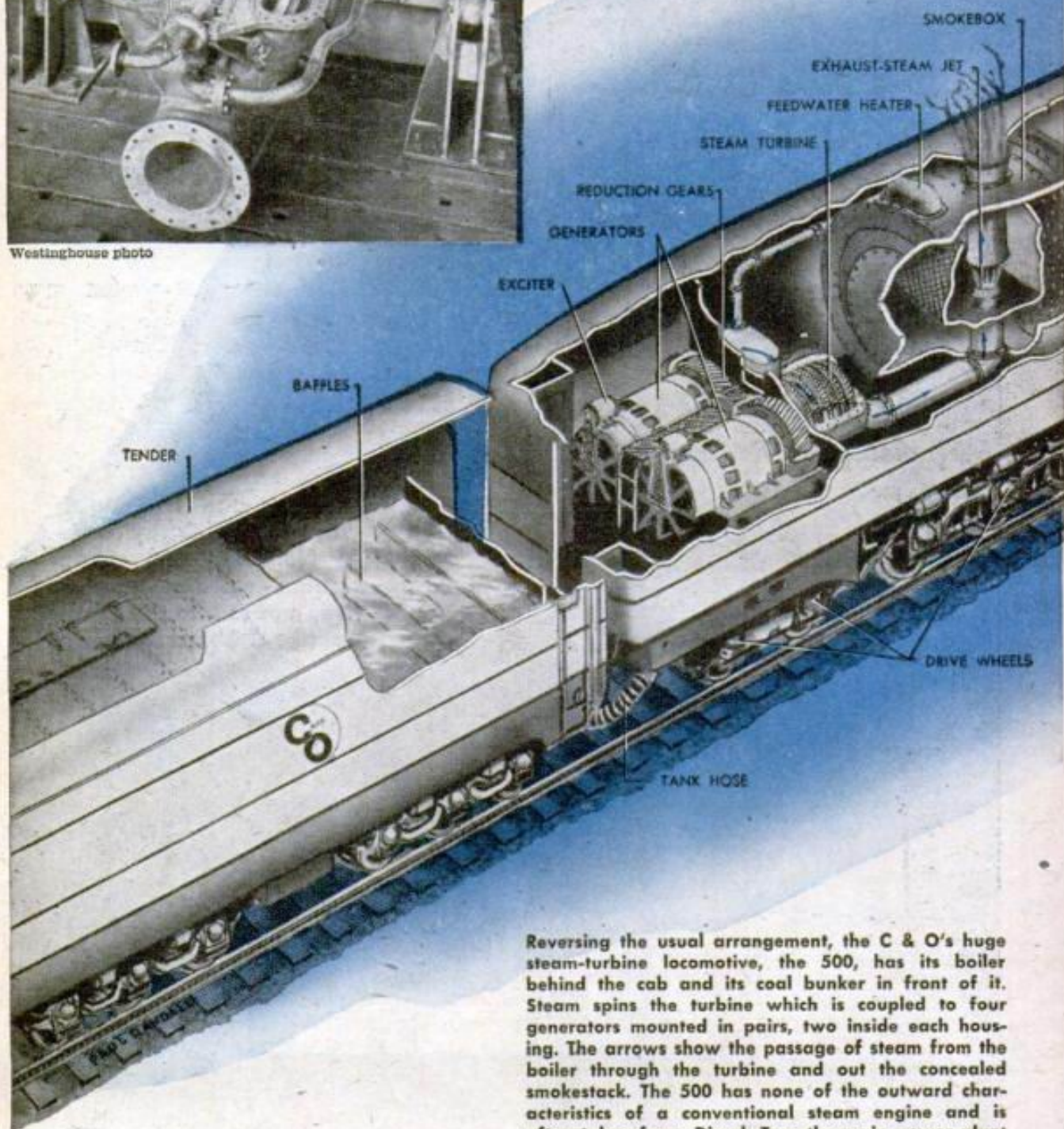
to modify and do not endanger pilots' lives. Flights are necessary because wind-tunnel research is limited at transsonic speeds.

In tunnels, at speeds near sound, shock waves set up by the wing's leading edge are reflected from the walls back onto the rear of the wing, distorting the results. Once the speed of sound is exceeded, the waves move back toward the trailing edge and the reflection no longer affects the wing.

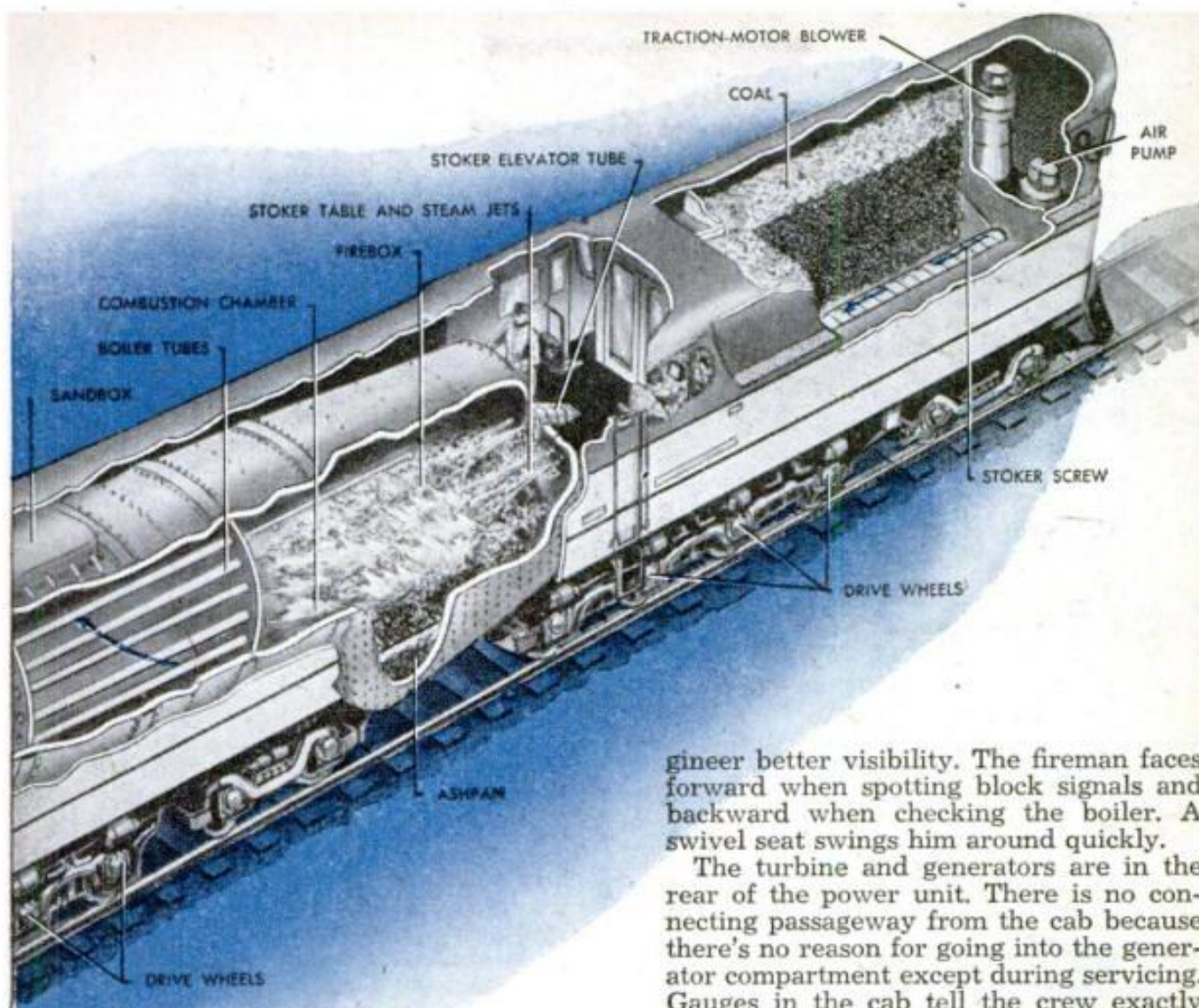


Westinghouse photo

It is the younger generation's salute to the veteran. Like the oldster in overalls, the orange and aluminum 500 is a coal-burning steam engine, but there the similarity ends. The new "baby" with its 29¼-ton coal bunker in front and its boiler and generators behind the cab represents the Chesapeake & Ohio's determination to bring the coal-burning iron horse up to date with the advantage of the electric drive; and to meet the efficiency of Diesel-electric challengers while side-stepping the threatened shortage of fuel oil.



Reversing the usual arrangement, the C & O's huge steam-turbine locomotive, the 500, has its boiler behind the cab and its coal bunker in front of it. Steam spins the turbine which is coupled to four generators mounted in pairs, two inside each housing. The arrows show the passage of steam from the boiler through the turbine and out the concealed smokestack. The 500 has none of the outward characteristics of a conventional steam engine and is often taken for a Diesel. Top, the main power plant before installation. Top housings for turbine and reduction gears are not yet in place. Generators are in the rear. Large pipe is the turbine exhaust



The C & O is, first of all, one of the leading coal-handling railroads and naturally favors coal as fuel. Second, its engineers point out that our oil reserves may suffice for only 25 to 30 years at present consumption, while our coal reserves are good for 2000 years. So they set about designing a locomotive that was as easy to maintain as a Diesel, as streamlined, as clean and quiet, and with high availability; but one that burned coal. Their answer is the 500.

There's a logical explanation for the reverse arrangement of the 500. The boiler had to be located where it would be adjacent to both the coal supply and the turbine. So, quite logically, it was placed between them. Coal feeds into the firebox by stoker from the front and steam roars out the rear end into the turbine. The boiler, a conventional fire-tube type, is mounted backwards. The firebox is toward the front and the smokestack toward the rear.

With this unusual design the cab could be moved farther forward giving the en-

gineer better visibility. The fireman faces forward when spotting block signals and backward when checking the boiler. A swivel seat swings him around quickly.

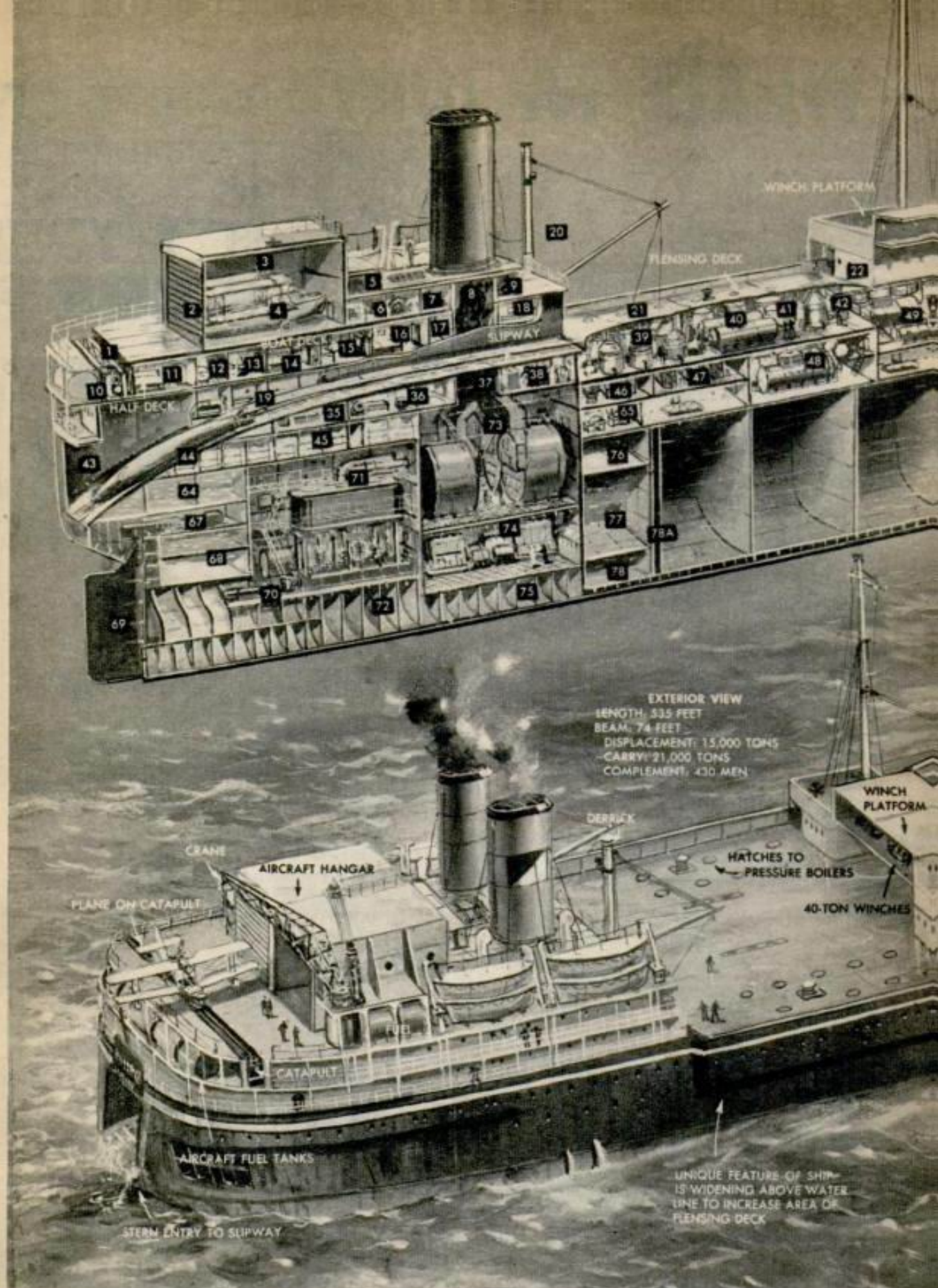
The turbine and generators are in the rear of the power unit. There is no connecting passageway from the cab because there's no reason for going into the generator compartment except during servicing. Gauges in the cab tell the crew exactly what is happening back there and adjustments can be made by cab controls.

Behind the power unit is the water tender—a mighty car in itself, holding 25,000 gallons of water. Two flexible water pipes connect it to the boiler.

The longest single-unit locomotive in the world, the 500 measures 154 feet $\frac{3}{4}$ inch from cowcatcher to rear coupler. This iron "race horse" is capable of speeds up to 100 miles an hour. At least that's its rated speed, but nobody knows how fast it will go. With 16 driving wheels powered by eight traction motors producing 4960 horsepower, the streamlined beauty won't take a back seat to anything on rails.

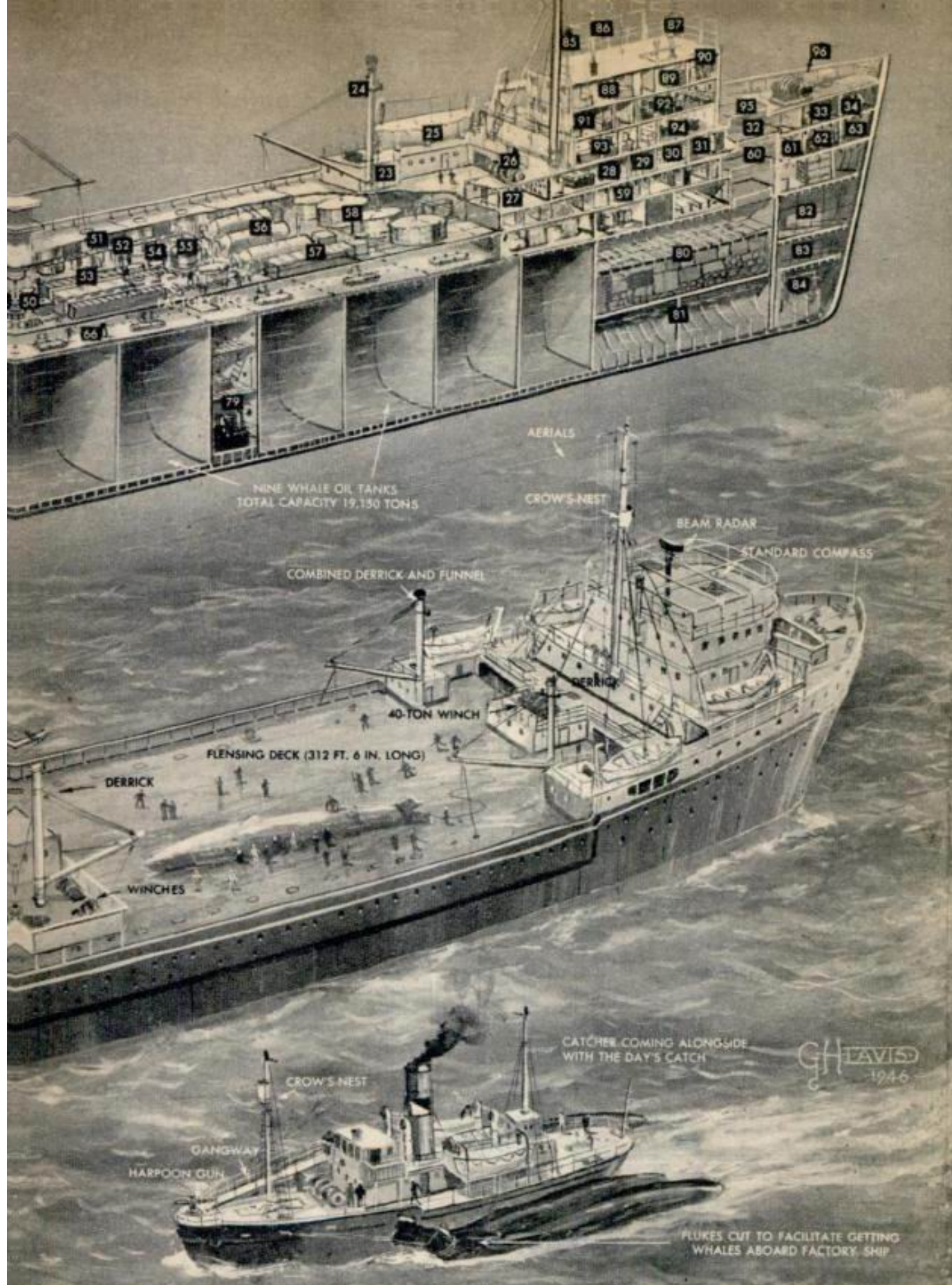
The 500 is really the second steam-turbine locomotive to go to work in this country. The first was the Pennsylvania's direct-drive steam turbine. But the 500 is the first steam locomotive using turbine-driven generators to provide electrical power for its drive wheels. It is steam's answer to Diesel and coal's answer to oil.

With its electric drive, controlling the 500 is as simple as regulating an electric



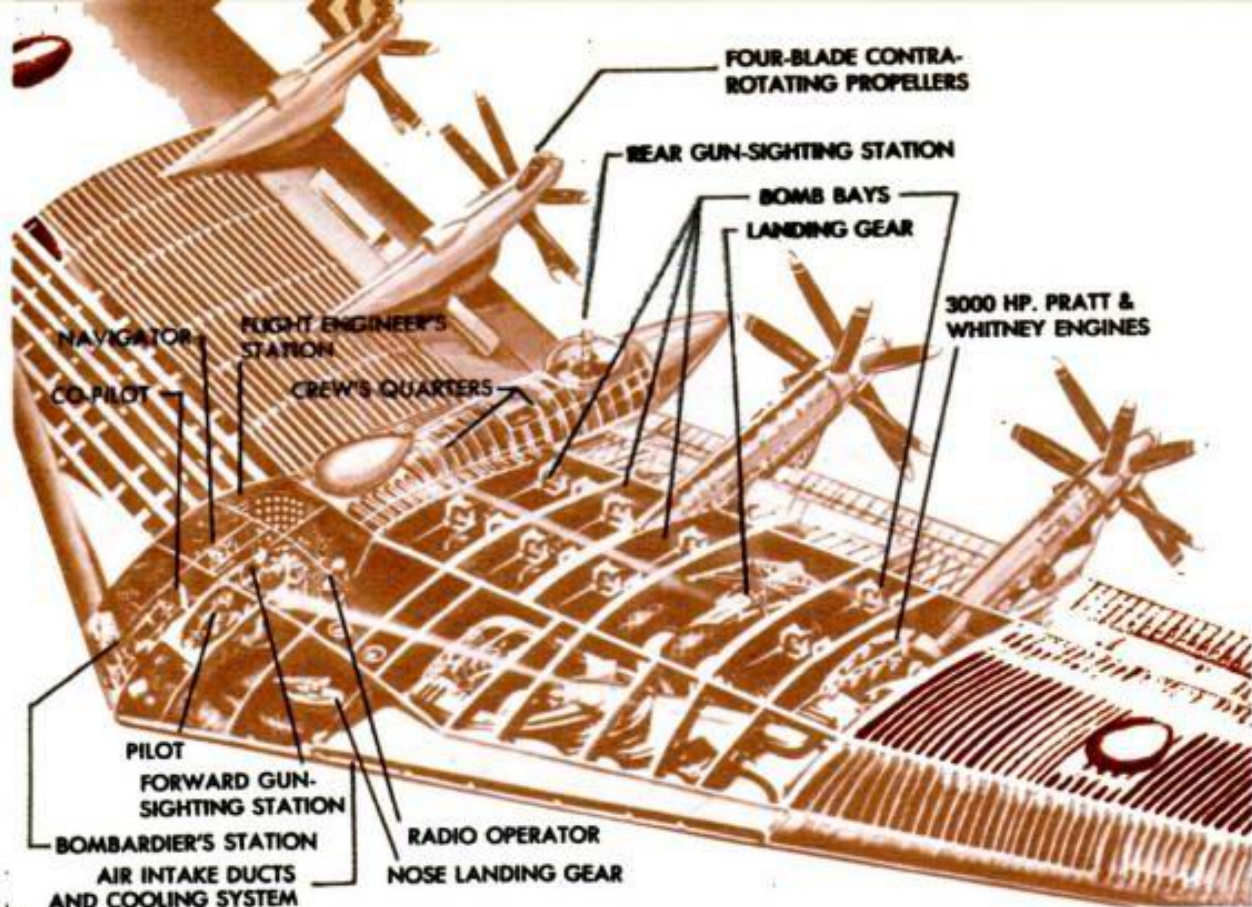
Sectional view of English whale factory ship shows, on boat deck: (1) aircraft catapault, (2) hangar roller shutter, (3) port hangar, (4) aircraft, (5) fans, (6) aircraft workshop, (7) fans, (8) port funnel uptake, (9) fans. On the halfdeck: (10) aircraft fuel tanks, (11) hospital, (12) bathrooms, (13) doctor's consulting room, (14) doctor's cabin, (15) dental surgery, (16) dental surgeon's cabin, (17) gangway, (18) assistant surgeons. On the flensing deck: (19) cookers' cabins, (20) derrick, (21) hatches to pressure boilers, (22) blacksmith shop, (23) carpenter shop,

(24) derrick and funnel, (25) lifeboat, (26) 40-ton winch, (27) electrical control room, (28) galley, (29) butcher shop, (30) pantry, (31) bakery, (32) hatch, (33) stewards' store, (34) boatswain's store. On upper flat: (35) seamen's laundry, (36) stewards' laundry, (37) funnel uptake, (38) bone drying plant, (39) blubber boilers, (40, 41 and 42) processing tanks. On the factory deck: (43) stern entrance to slipway, (44) whale being drawn up slipway, (45) cabins for workers, (46) drier, (47) meat meal plant, (48) separators, (49) liver plant, (50) mixture tanks,



(51) pressure boilers, (52) conveyor, (53) driers, (54) settling tanks, (55) separators, (56) cookers, (57) cutting machinery, (58) driers, (59) freezing compartment, (60) hatch, (61) harpoon stores, (62) chain lockers, (63) stores. Lower flat: (64) fresh water tanks, (65) knife sharpening room, (66) tank tops. Lower hold: (67) steering gear, (68) water ballast tanks, (69) rudder, (70) propeller shaft, (71) triple expansion steam propulsion engine, (72) fresh-water tanks, (73) boiler room, (74) generators, (75) fuel tanks, (76) Diesel oil tanks, (77) settling

tank, (78) fuel tank, (79) pump rooms, (80) fore-hold, (81) fore deep tanks, (82 and 83) fresh-water or ballast tanks, (84) reinforced bow frames. Bridge and superstructure: (85) foremast, (86) beam radar, (87) master compass, (88) wireless cabin, (89) captain's chartroom, (90) wheelhouse, (91) officers' cabins, (92) dining room, (93) officers' and chief stewards' cabins, (94) mess and smoke rooms, (95) hatch, (96) windlass. This cutaway drawing was made of the new Balaena, 15,000-ton whaling ship built in Belfast for United Whalers Ltd. of London.

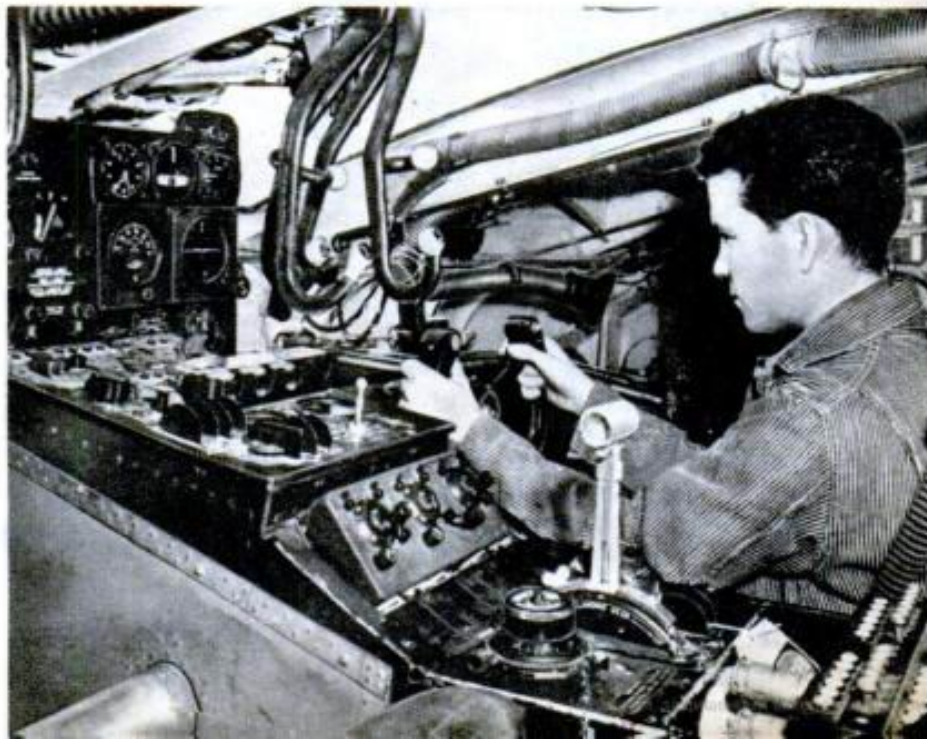


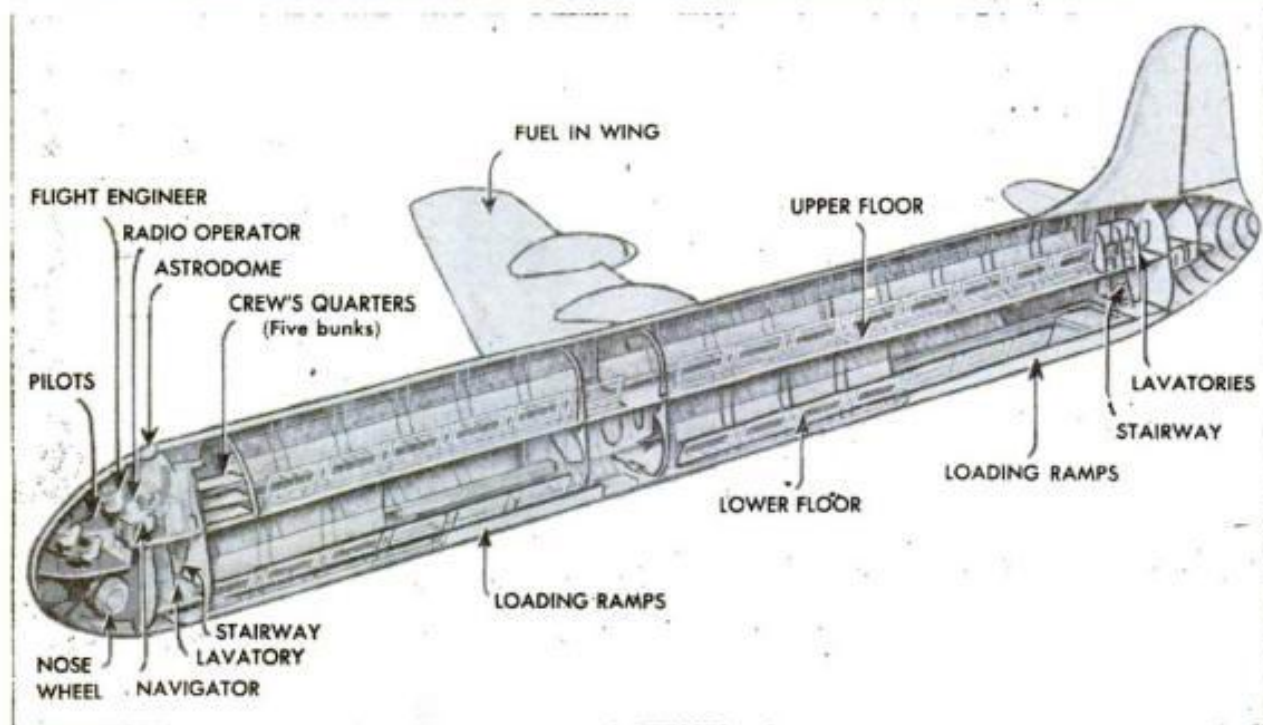
Inside the Flying Wing

Here's how crew and instruments fit inside the huge Northrop B-35, which is 39 tons heavier than the B-29 and has a range of at least 10,000 miles. The 15 men are in a pressurized center section 37½ feet long, with the pilot sitting in a raised nacelle at the extreme nose. The wing has a span of 172 feet and a gross peak load of 104 tons. Fourteen more are being built for the Army Air Forces



Without leaving his chair, the flight engineer (left below) can watch all of the instruments mounted on a curved wall. Forward vision for the copilot (right below) is through a plastic panel in the wing's leading edge





Consolidated-Vultee photo and sketch

AAF Plane to Carry 400 Troops

No building is big enough at the Consolidated plant to house the nearly completed XC-99 troop transport, world's largest land-based plane. An extensive ground testing program will start as soon as land-

ing wheels, wing sections and engines are installed. The double-deck version of the B-36 bomber will carry 400 troops, 335 litter patients or 100,000 pounds of cargo. It will have a range of more than 8000 miles.

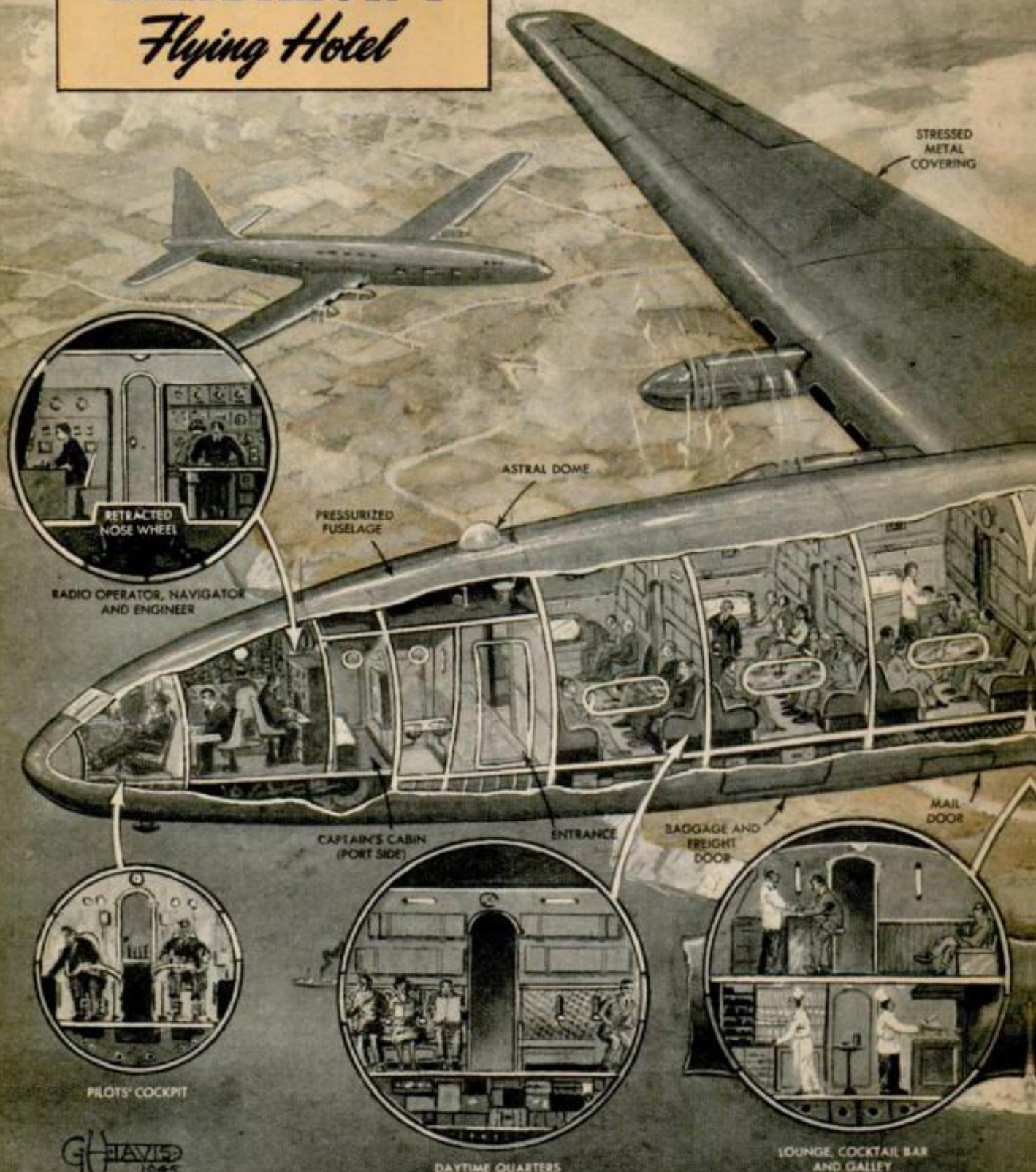
Blood-Typing of Newborn Babies May Help Avoid Hospital Mix-Ups

Newborn babies should be blood-typed instead of footprinted in hospitals to avoid mix-ups in identification, according to Dr. Malcolm A. Hyman of the Jewish Hospital of Brooklyn. A total of 360 different types of human blood can be identified through varying factors in blood composition. Dr. Hyman advocates taking a sample of blood

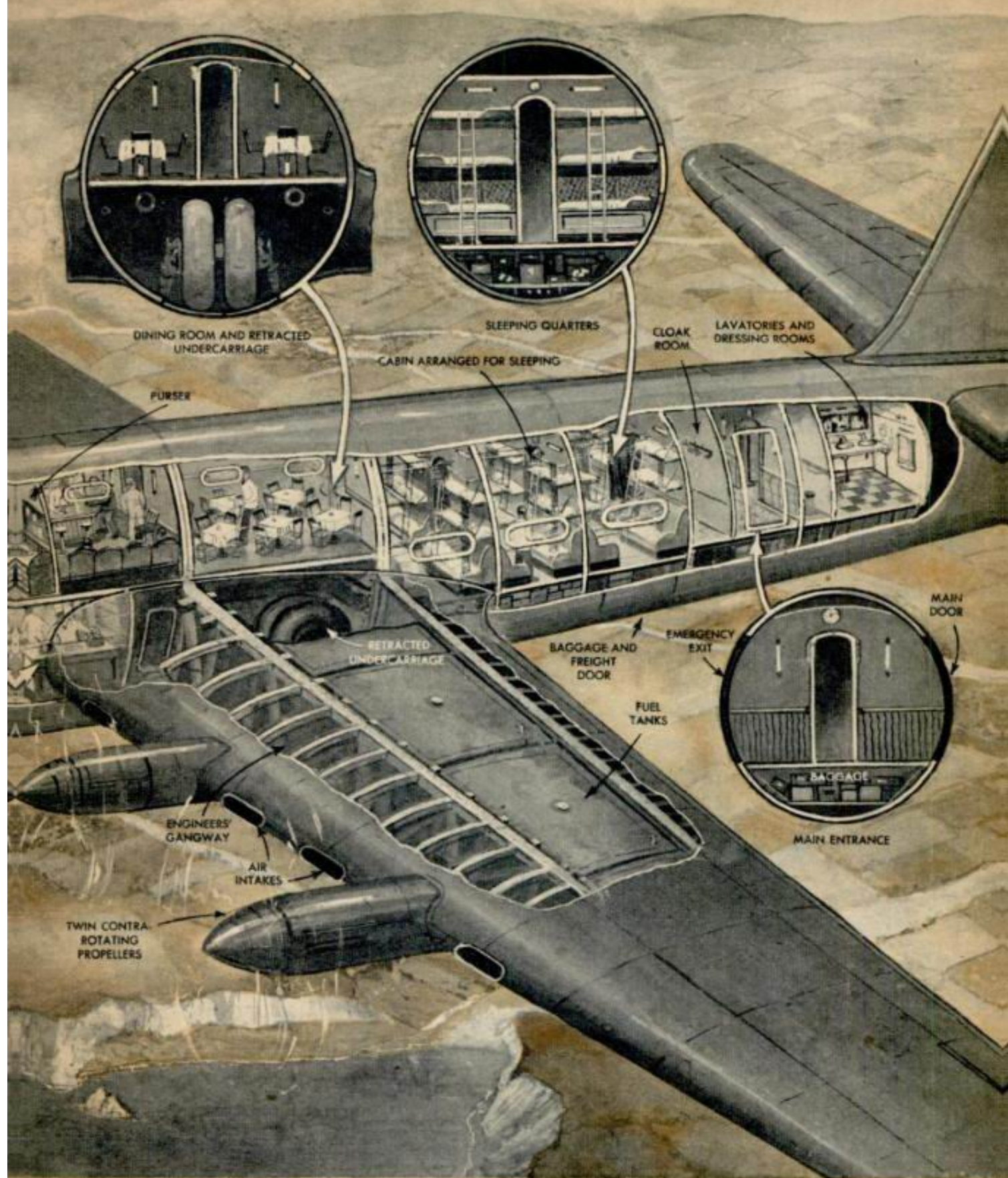
from the baby immediately after birth and attaching this to the mother. Later if there is any doubt as to the child's identity another sample can be taken and compared with the first. Dr. Hyman points out that footprints change completely within a month after birth but that the chemical pattern of blood is unchanging.

"BRABAZON 1"

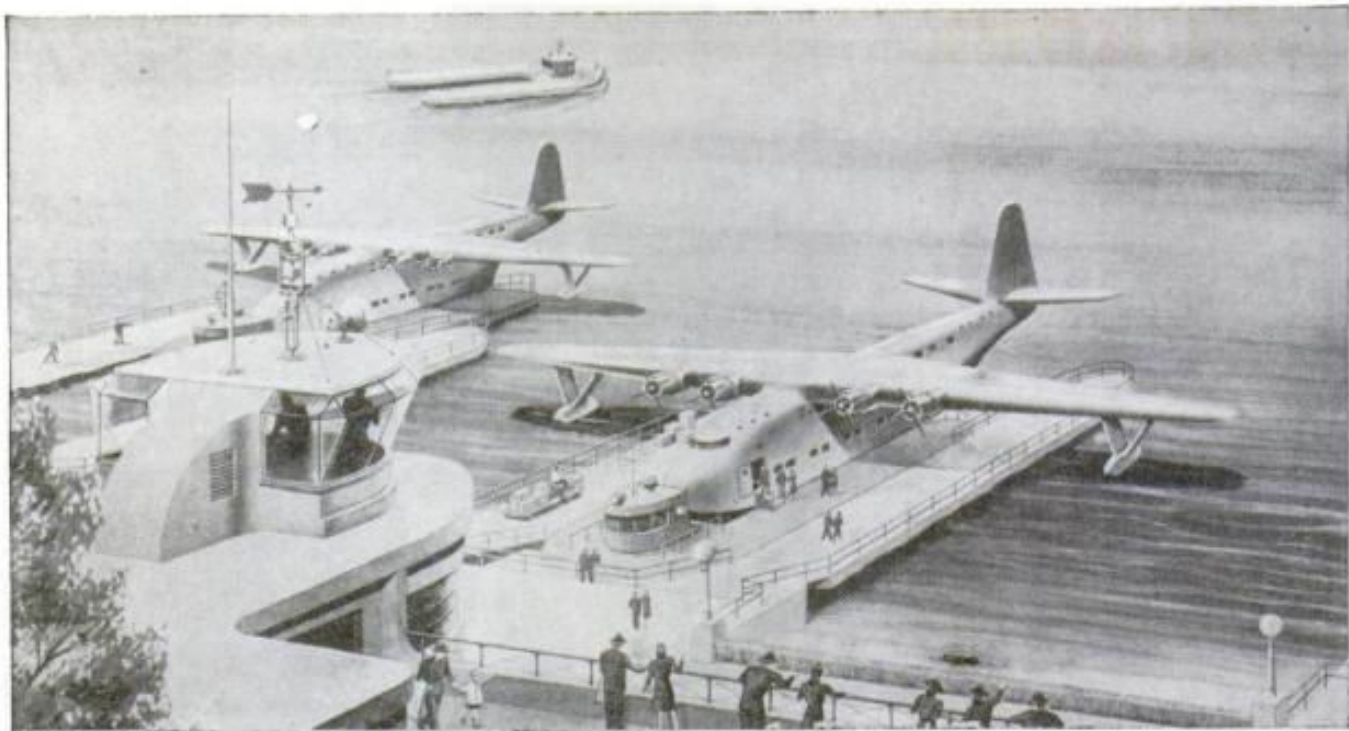
Flying Hotel



Nearing completion at Bristol, England, is a plywood mockup of Great Britain's largest airliner, the 110-ton Brabazon 1. Although its dimensions have not been officially announced, the wing span is reported to be approximately 270 feet and the overall length nearly 160 feet. It is estimated that the four 2500-horsepower engines, with contrarotating propellers, will give the plane a range of 5000 miles at a 250-mile-an-hour cruising speed. Flights between Australia and England in 48 hours are expected for the plane. One hundred and thirty feet of the fuselage's length will be pressurized. A short-haul version of the Brabazon, named after



a pioneer English airman, Lord Brabazon, will carry 224 passengers. The long distance type illustrated above will sleep 72. There will be two main passenger salons, separated by a full-height double-deck section housing a cocktail and snack bar, lounge and dining room above and a galley, purser's office and part of the auxiliary gear below. Each main salon will be divided into three compartments, with seats accommodating three passengers facing forward and three to the rear on either side of the aisle. A triple-decker berth arrangement will take care of each compartment's 12 daytime occupants at night. The plane is expected to be ready in 1947



This is Glenn L. Martin Company's conception of facilities for handling seaplane passengers and freight, featured by U-shaped boats to tow planes and U-shaped docks. Idlewild Airport will have a special seaplane base

continue to operate at full capacity after Idlewild goes into use. In fact, LaGuardia will be expanded outward into Flushing Bay, and will handle short distance flights of about a 1000-mile radius. Transcontinental, intercontinental and transatlantic flights will have their terminals at Idlewild.

Site of the new airport, on lowlands around the bay, created a stupendous engineering problem for Jay Downer, engineer, and Wharton Green, associate engineer, who prepared the general layout and are supervising construction. Delano and Aldrich are the architects for all the airport buildings.

Forty-one million cubic yards of sand fill have been placed on the site by hydraulic suction dredges in the bay. E. J. Carrillo, field engineer, declared that 12 million more cubic yards of fill will be placed under the next contract for the second phase of operations, and eight million more will be added in future operations. About 10 feet of fill covers the original marshland, Mr. Carrillo said, and a total subsidence of two feet occurred over the site. No further settlement trouble is expected.

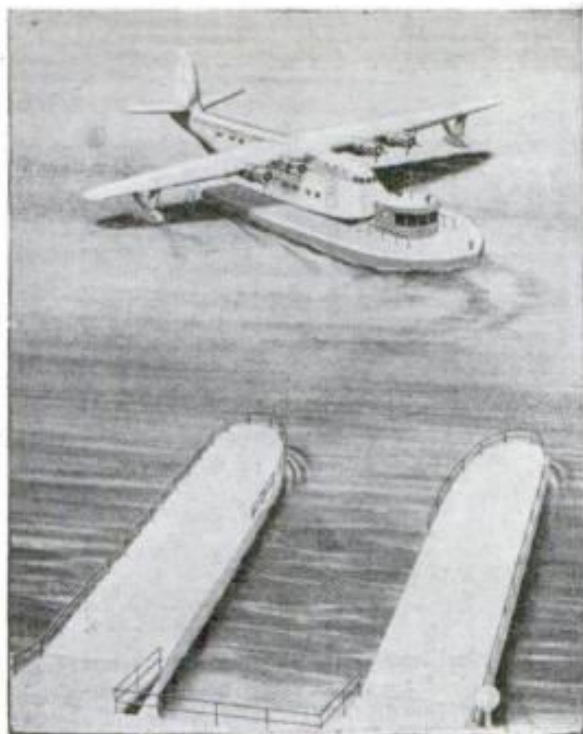
The airport runs five miles to the east and west, and two and three fourths miles north and south. The completed runways A, B and C are just half of the principal runways and the three others, D, 10,000 feet long, E, 6000 feet, and F, 7700 feet, are scheduled for use in 1947. Six additional runways are provided in the plans, with construction scheduled for completion in 1950. Tentative plans for these runways call for U, 6000 feet, V, 5650 feet, W, 6000

feet, X, 5200 feet, Y, 6000 feet and Z, 6000 feet. Experience gained in operation of the first six major runways will be applied to the future runways and specifications for the latter may be altered as a result.

Drainage of the low-lying area created the greatest problem encountered in the first stage of construction. Although the 10 feet of sand fill covers 3000 acres now and eventually will cover the entire site, contractors on foundation work have found it necessary to add more fill when they reached the muck beneath the first layer. Drainage trenches crisscross the field and a gigantic three-barreled storm sewer, 8400 feet long, is being laid to assure proper permanent drainage. Water from the storm sewer goes into Bergen Basin, a manufactured waterway at the edge of the airport that is 200 feet wide at the bottom, 6000 feet long and 30 feet deep. Two million cubic yards of earth were dredged from the bay to create Bergen Basin.

Choice of the site was made to provide both land and seaplanes with excellent landing facilities. The location on the bay assures a 15,000-foot basin and seaway for the largest flying boats envisioned for ocean travel. In addition, ocean-going tankers will unload their cargoes of fuel directly into airport storage tanks.

The three completed runways were designed to eliminate any waviness caused by taxiing heavily loaded airplanes, and the 12-inch-thick reinforced concrete is believed ample to assure permanent smoothness. Each 200-foot runway has a 50-foot shoulder of bituminous material on both



Hydraulic pipe bender that exerts 40-ton pressure twists steel pipe into desired shapes for electrical conduits at the airport

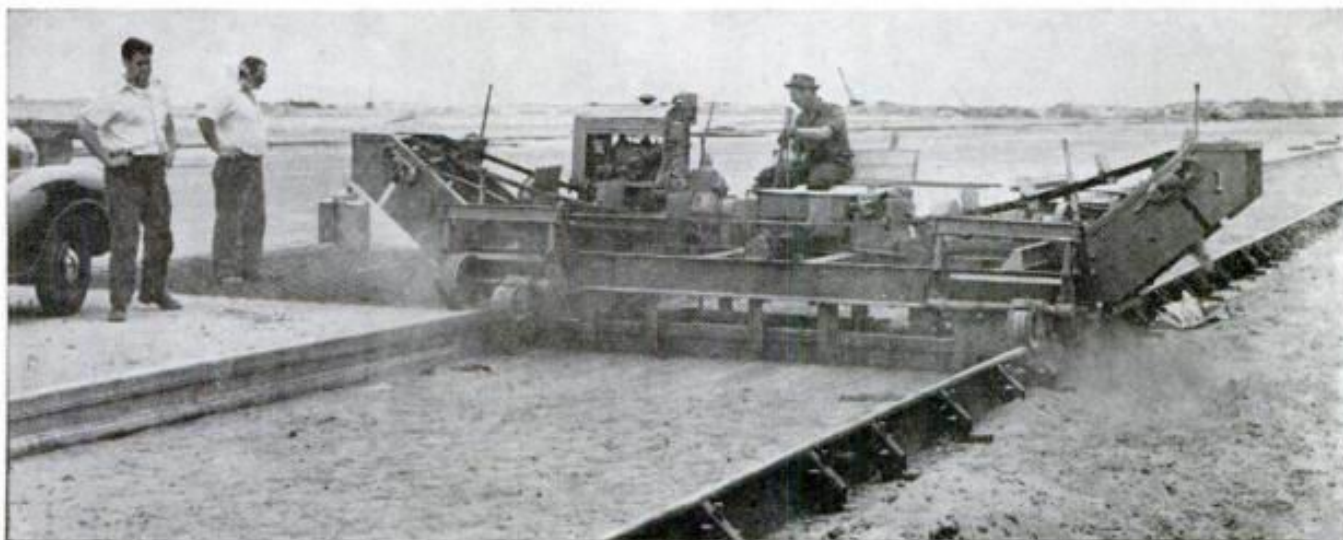
sides. This material can be ripped up easily and replaced by concrete should wider runways be desired in the future.

Newest types of giant earthmoving machinery, graders and concrete mixers, dredges and shovels are employed in construction of Idlewild. Specially designed for the operation are six planting machines which plant long bladed beach grass in the sand fill to anchor it and prevent erosion. The beach grass is brought in from the beaches farther out on Long Island, and completion of the planting is hampered only by a shortage of supply. Eight men ride on each tractor-drawn planter. Three are kept busy extracting stalks from

(Continued to page 160)



A surveyor lays out the line for 8400 feet of sewer pipe to drain low marshlands. Below, self-propelled subgrader moves ahead of concrete mixer to smooth surfaces for a long runway



POPULAR MECHANICS MAGAZINE

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SEE PAGE 12

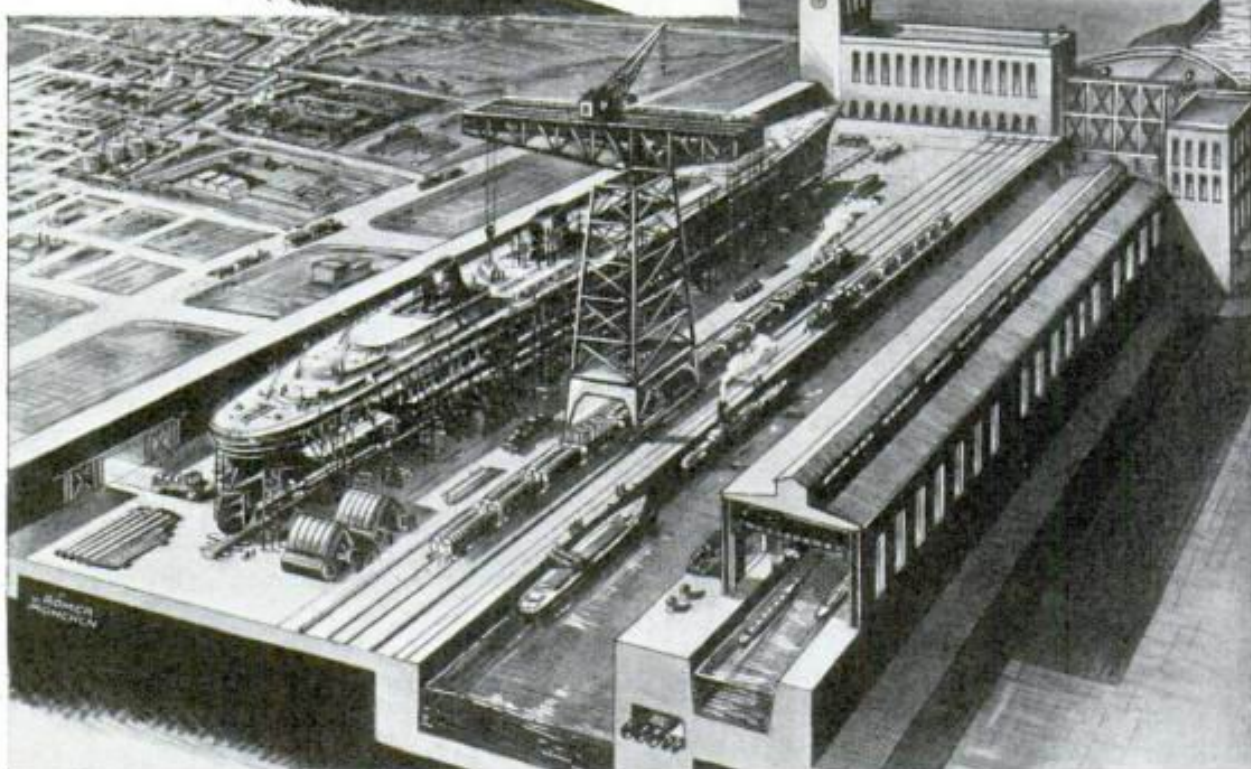
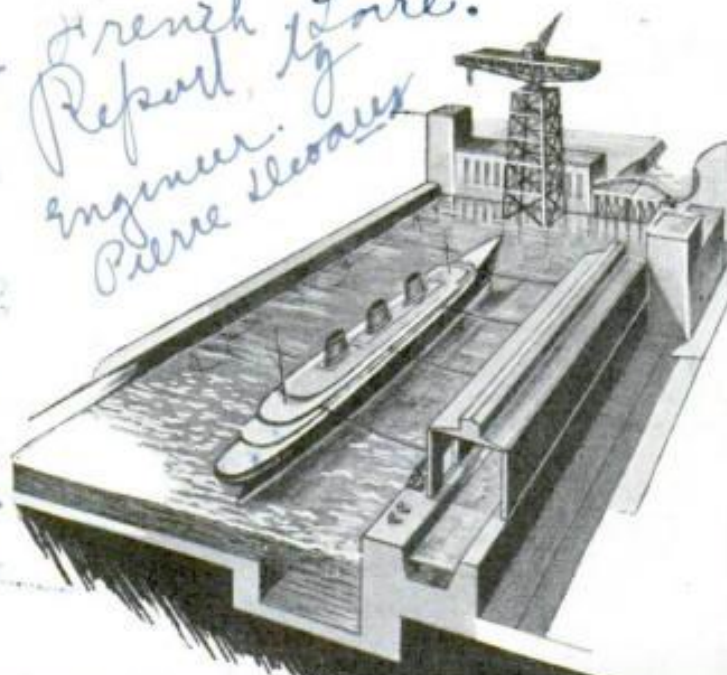


VICTORY
LOAN

Floating Ship in Dry Dock Replaces Launching

Danger of capsizing a ship or damaging the hull in launching is avoided, and many difficult engineering problems are eliminated with a dry dock which floats ships merely by pumping water into an enclosure. If a ship is to be launched, the keel is laid on a slanting slip of strong blocks requiring geometrical accuracy, and, of course, the ship must be floated on level

keel when she is ready for interior appointments and equipment. In the new dockyard, a large ocean steamer may be built from the start on level, dry ground, its floor being above water level. The dockyard consists of an enclosure 1,000 feet long and 400 feet wide, closed at both sides by strong walls. Gates at either end remain open for hauling material during the construction period. Along one side of the dock is a slip which provides an outlet to open water. When the ship is to be floated for finishing touches, the gates are closed and sealed, and water is pumped into the dry dock. Afloat, the boat is towed by windlass and ropes into the slip from where it is floated to open water after the levels are equalized. A huge crane, which can lift 240 tons, carries heavy parts and material to the ship while under construction.

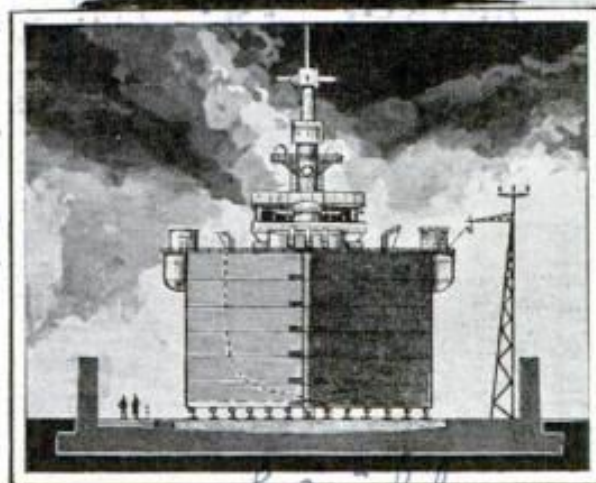
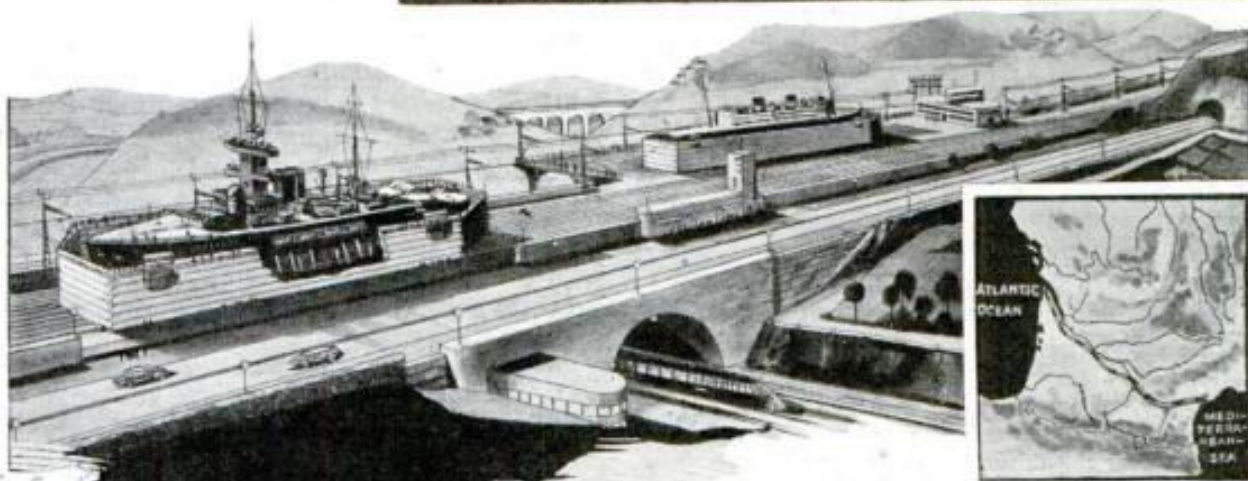
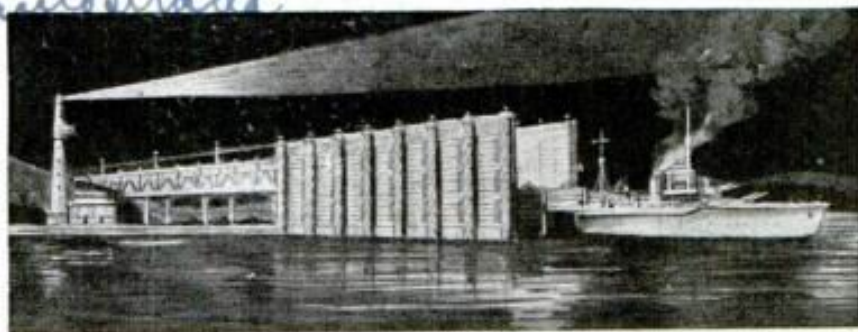


Ship under construction in the dry dock. When hull is completed and ready for interior finishing, the crane travels to the far end, as shown above, and water is pumped in so boat may be towed to slip at side

300-Mile Railway to Carry Ships Is Planned

navtoload

Right, ship entering lock to be raised to track. Center, as ship would appear on cross-country railroad. Bottom, position of ship in carrier is shown in outline. Inset, map of route



© Three Lions

means of electric power along a six-track railroad across the country. A regular railway for fast trains and two motor roads also would be part of the project. Captive balloon barricades are being considered as a means of defending the railway against enemy air raids. The balloons, spaced at 900 to 1,050 feet, would support steel nets at an altitude great enough to reduce the chance of successful bombing. The railway also could be used to speed up passage of trading ships from French ports to the Mediterranean.

L. mahl
French engineers are preparing plans for a ship-carrying railway, 300 miles long, between Port le Verdon and Beziers, linking the Atlantic and the Mediterranean. A similar line, but much shorter, already exists in East Prussia. The proposed railway, which would eliminate a 1,200-mile water trip from the Bay of Biscay to the Mediterranean, by way of Gibraltar, would enable the French Atlantic fleet to move quickly in emergencies. Rough drafts of the project call for a shipping port where ships would be put into movable docks, which then would roll by

U. S. Has 23,000 Aircraft Pilots and Half as Many Planes

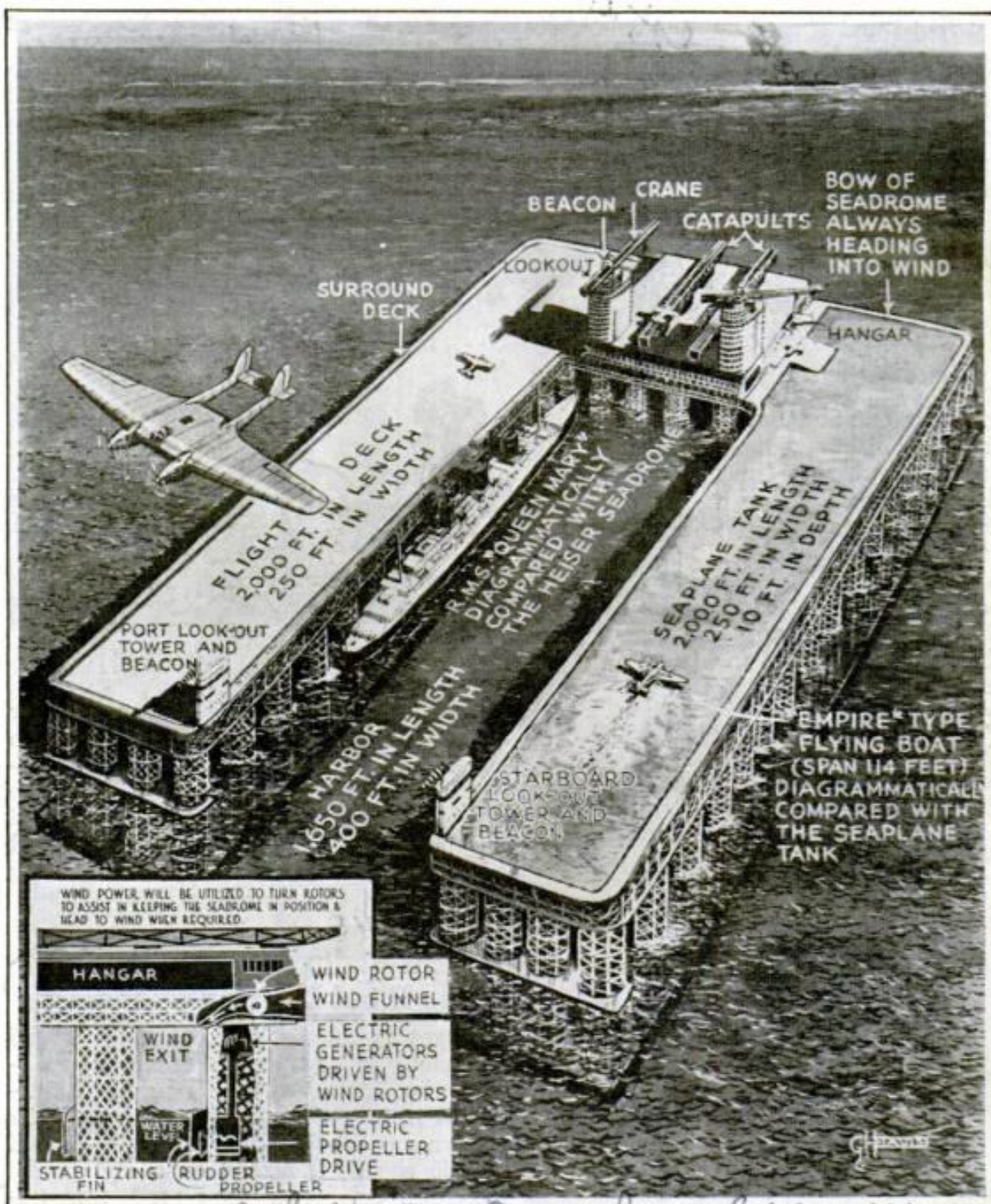
Coincidental with the announcement of federal administration plans to train 20,000 aircraft pilots each year, the Civil Aeronautics Authority made known that there were 22,983 licensed pilots in the United States on January 1. Of these, 1,159 were air line pilots, 10,676 held private licenses and 6,834 commercial licenses. Women pilots numbered 675. The aircraft census showed 11,159 certified or uncertified planes, and 221 gliders with 172 licensed glider pilots.

Science Service
1/9/39

Washington, D.C.

Is 263.

Floating Base Proposed for Ocean Air Liners



M.E. Heiser, Australian Engineer.

This is a drawing of the Heiser seadrome, proposed as a means of permitting land or sea planes to break their flights between Europe and the United States. The seadrome is U-shaped, with a 2,000-foot tank for flying boats and a 2,000-foot deck for land planes. Inside the "U" is a ship harbor, 1,650 feet long and 400 feet wide, large enough for liners of the "Queen Mary" type. The seadrome would not be anchored. It would be constructed of steel tubes built up on girder-work columns mounted on pontoons sunk 150 feet below the action of wave currents. Air currents agitate water to a depth of sixty feet, at which point pressure increases with depth until there is enough upward force to sustain the structure in position as the centrifugal force of the earth keeps the ocean in place. To help hold the seadrome into the wind, wind rotors would drive generators to supply power for twelve giant propellers. Two large rudders would be used for steering.

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TECH UPDATE

News Of Tomorrow's Technology Today



PM ILLUSTRATION BY PAUL DIMARE

Air-Powered EI Train Would Hit 300 Mph

ESSINGTON, PA—Hanging from trolleys that race through guide tubes 35 ft. above the ground, an aerial train could zip from station to station while hugging the curves of existing railroad rights of way.

Conceived by helicopter pioneer Frank Piasecki, these AirTrains would be driven by ducted, variable-pitch propellers—without the heavyweight train equipment normally needed to press wheel against rail. Braking is achieved by reversing propeller pitch.

Overhead, the 10-wheeled tubeway trolleys would roll along five rails, arranged in a nonderailable configuration. Since the rail system doesn't

rely on friction to generate movement and stopping power, the cars can weigh as little as a fuselage. The entire tubeway structure can thus be lighter and cheaper to construct.

To keep passengers comfortable at high speed, an active suspension and aerodynamic canard surfaces would compensate for any bumps in the overhead tubeway. And the strut that links car with trolley would swing on a hinge, banking as the car hit curves.

Mixing proven wheel-on-rail and aircraft technologies, the AirTrain may be a

cheap alternative to magnetic levitation for our next-generation ground transport system, Piasecki says.

Prop-driven AirTrain cars, each carrying 90 passengers, follow contours of 20th-century rail lines at 300 mph.

Highlights This Month

- **Robo-Copter**—Pilotless chopper hops from ship's deck.
- **Mechanical Marathon**—Robots hold their first Olympic Games.
- **Smart Suits**—High-tech tailoring for Moonwalkers.
- **ATF Shootout**—Future fighter prototypes duel for the title.
- **Air Brakes**—Retro-rockets soften chute landing.
- **Mussel Machine**—Swimming robot tackles pesky zebra mussels.

Editor: Abe Danc
Assistant Editor: Greg Pope
Contributors: Mike Fillon, William Siuru

★ SOVIET SUPER FIGHTERS

KATSUHIKO TORIYAGA PHOTO



ROBIN ADRIAN PHOTO



THE COBRA MANEUVER

Cobra maneuver wows crowds, but also shows the Su-27's deadly aim.



PM ILLUSTRATION BY FRED WOLFF

seem relatively primitive. Both bear similarities to the early Grumman F-14s and McDonnell Douglas F-15s built in the 1970s. Round dial instruments have not yet been replaced by multifunction video displays, and the level of cockpit system integration is well below that found in the F/A-18 or in later versions of the F-16, F-15 and F-14.

It would be misleading to say that this results solely from the Soviets' belief that under combat conditions only simple solutions lead to victory. The Soviets simply do not have the computer technology required for cockpit displays or system integration on par with the latest Western aircraft. This may change in the near future, however. The Mikoyan bureau is flying a MiG-29 with digital flight controls, and both Sukhoi and Mikoyan have fighters flying with multifunction displays installed.

Both Soviet aircraft employ an infrared search-and-track system that the United States is just now perfecting. Unlike radar, infrared sensors emit no radiation, so they can be used



Viktor Pougachev gestures to explain the Cobra to author (in cockpit). Russian pilots displayed exceptional skills.

to lock onto a target and launch weapons, without tripping warning receivers aboard the target craft. The F-14D, the first American aircraft with this ability built-in, will not be incorporated into the fleet for another two years.

Flight of the Fulcrum

Following my preflight check and cockpit checkout in the static display MiG-29, the weather cleared enough for Menitsky to fly the 2-seat MiG-29UB into Kubinka from the still-secret Soviet Zhukovsky flight-test station.

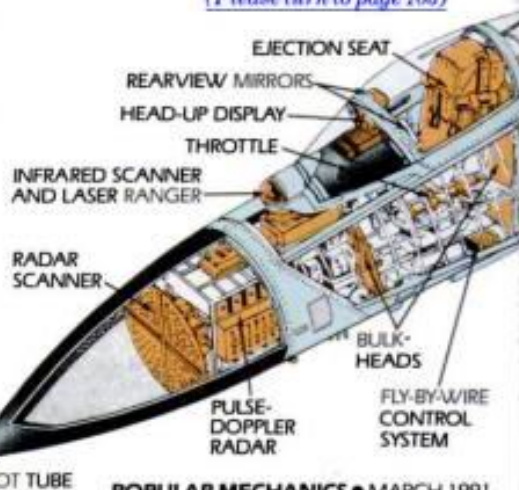
Su-27

With a rip-snorting 55,000 pounds of thrust on tap, the Su-27 hustles through the sky at up to 1550 mph. High angle of attack maneuvers (left) send vapor billowing over the wings. Cockpit (below left) is nearly identical to MiG-29.



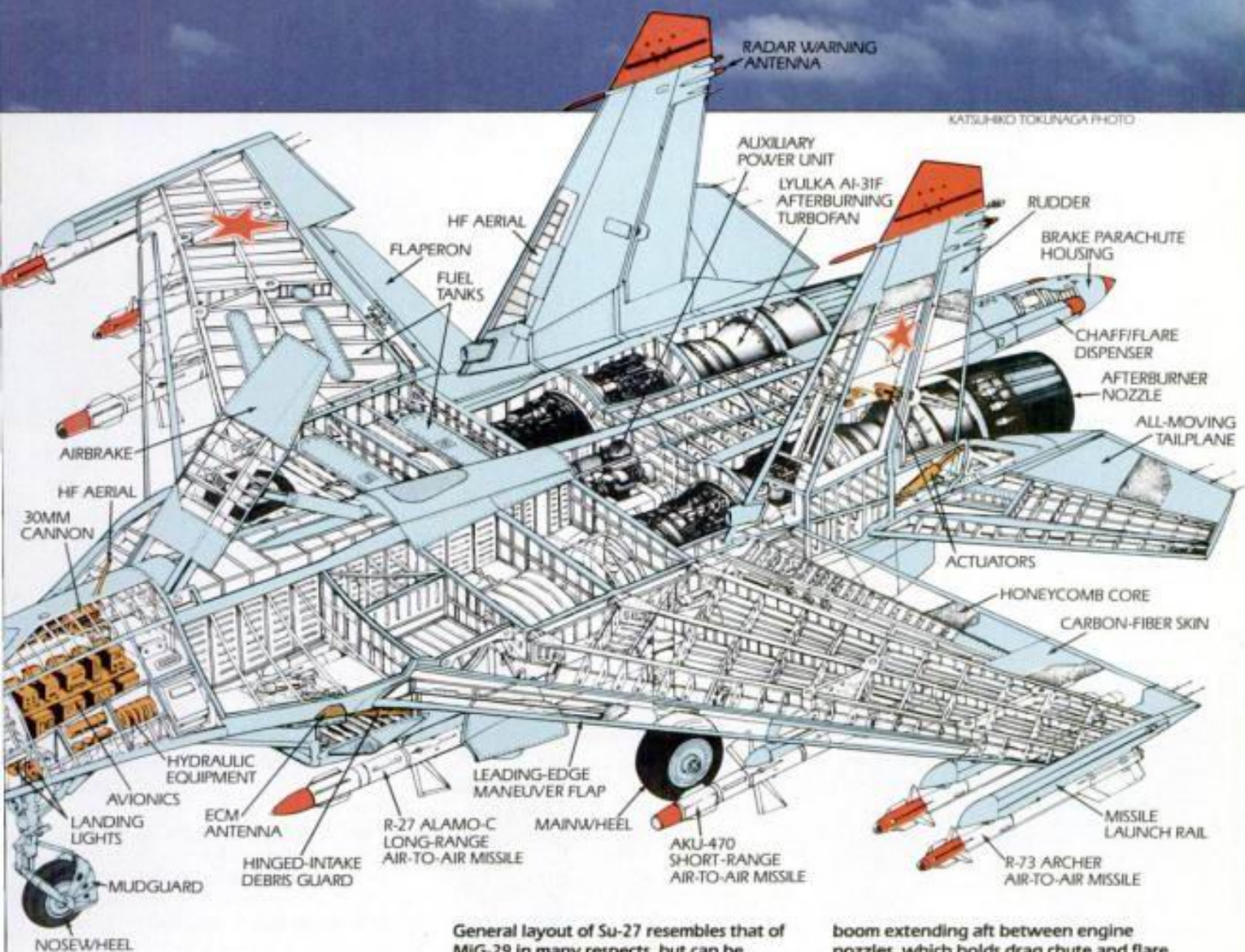
Because it was now late in the day, and the weather was still overcast, it was decided that I would fly from the back seat. I was fitted with Soviet flight gear. The Soviets use a bib-type flight suit with a separate jacket. The G-suit is similar to U.S. designs, but is worn under the flight suit. All in all, the flight gear and Soviet-style helmet fit very well.

Visibility from the front seat of the MiG-29 is excellent, but from the back
(Please turn to page 103)





KATSUHIKO TOKUNAGA PHOTO



General layout of Su-27 resembles that of MiG-29 in many respects, but can be recognized by center-mounted IR sensor, large speed brake behind cockpit, and

boom extending aft between engine nozzles, which holds drag chute and flare dispenser. Large internal fuel storage areas provide 2500-mile range.

PILOT PRESS ILLUSTRATION



MIg-29

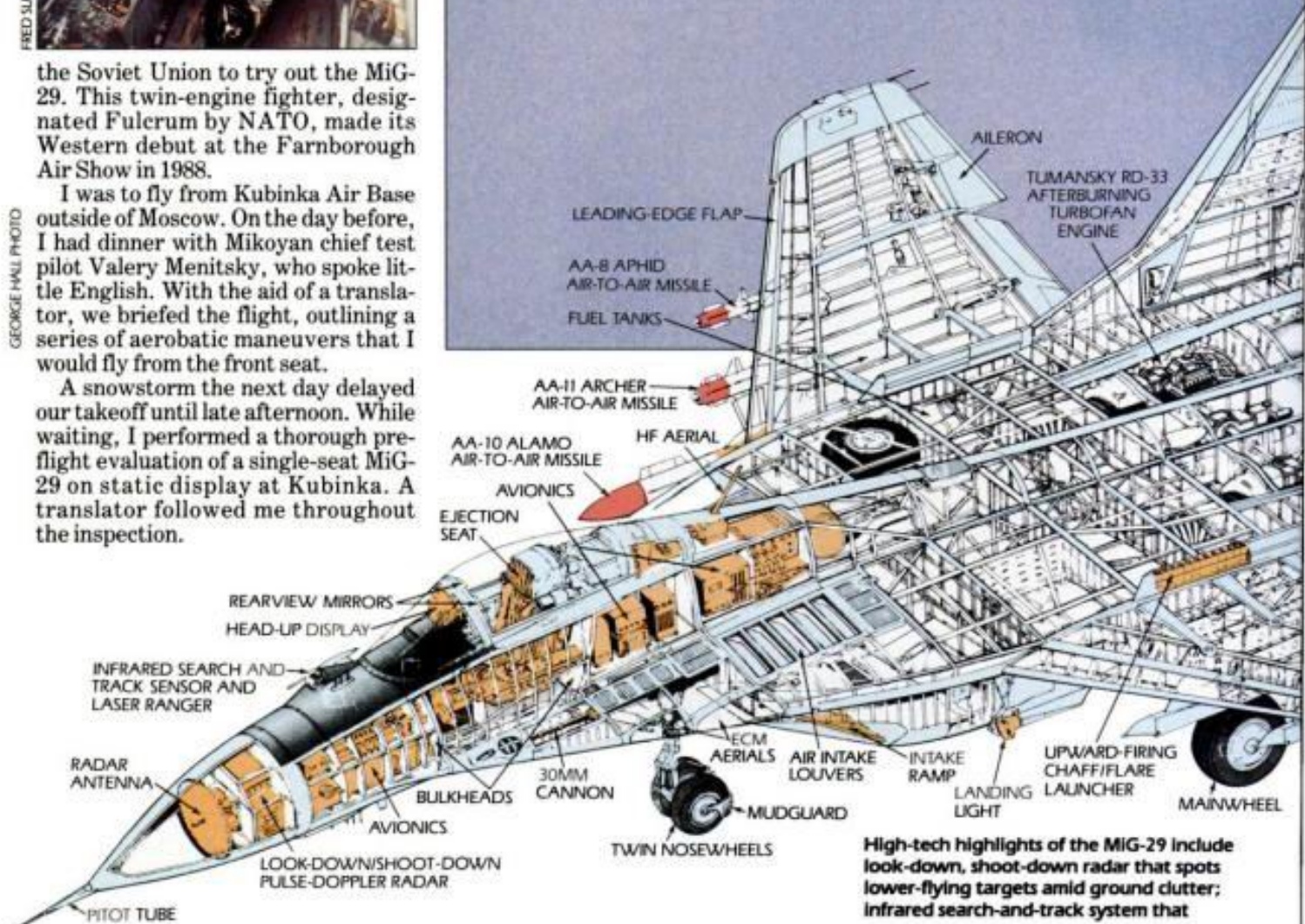
36,600 pounds of thrust provided by twin Tumansky engines lets the MiG-29 fly straight skyward (above left), while superb aerodynamics permit high-G maneuvers. Cockpit instruments (left) are surprisingly primitive, consisting entirely of round dial gauges.

the Soviet Union to try out the MiG-29. This twin-engine fighter, designated Fulcrum by NATO, made its Western debut at the Farnborough Air Show in 1988.

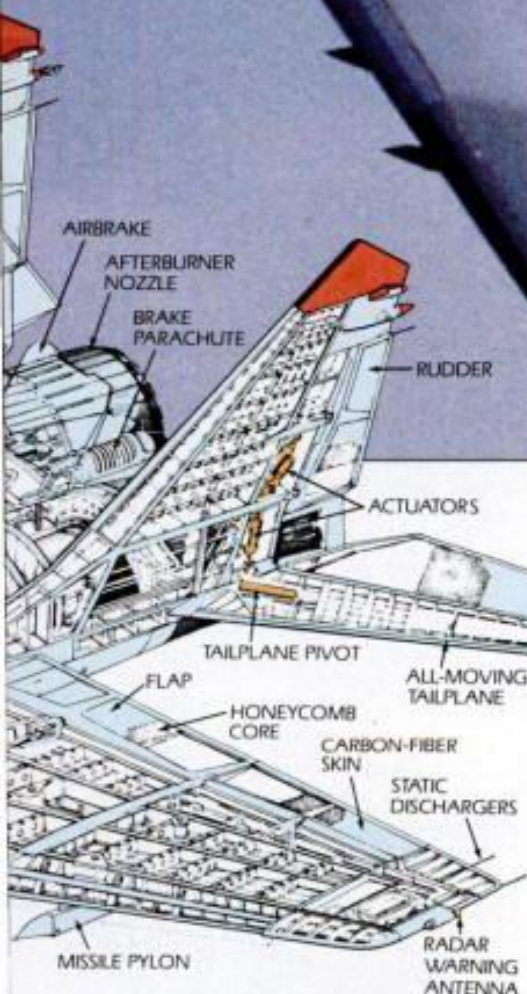
I was to fly from Kubinka Air Base outside of Moscow. On the day before, I had dinner with Mikoyan chief test pilot Valery Menitsky, who spoke little English. With the aid of a translator, we briefed the flight, outlining a series of aerobatic maneuvers that I would fly from the front seat.

A snowstorm the next day delayed our takeoff until late afternoon. While waiting, I performed a thorough pre-flight evaluation of a single-seat MiG-29 on static display at Kubinka. A translator followed me throughout the inspection.

FRED SLUTTER PHOTOS



High-tech highlights of the MiG-29 include look-down, shoot-down radar that spots lower-flying targets amid ground clutter; infrared search-and-track system that



enables pilot to see without being seen, and above-wing intake louvers that feed air to engines when main intakes close to protect against foreign object damage.

Simple but effective

Current-generation Soviet fighters represent a great stride forward in the use of new technology, particularly look-down, shoot-down radars, infrared search-and-track systems, and improved turbine engines.

At the same time, the planes represent the Soviet design philosophy of building simple and reliable aircraft. Inspecting the outside of the MiG-29 revealed large, welded-steel structures in the airframe. The Soviets use spot-welds without worrying about the pattern. In noncritical areas, such as access panels and landing gear doors, the fasteners were not always flush, and the rivet alignments seemed unimportant.

Such indifference to detail contrasts sharply with the smooth surfaces of the McDonnell Douglas F/A-

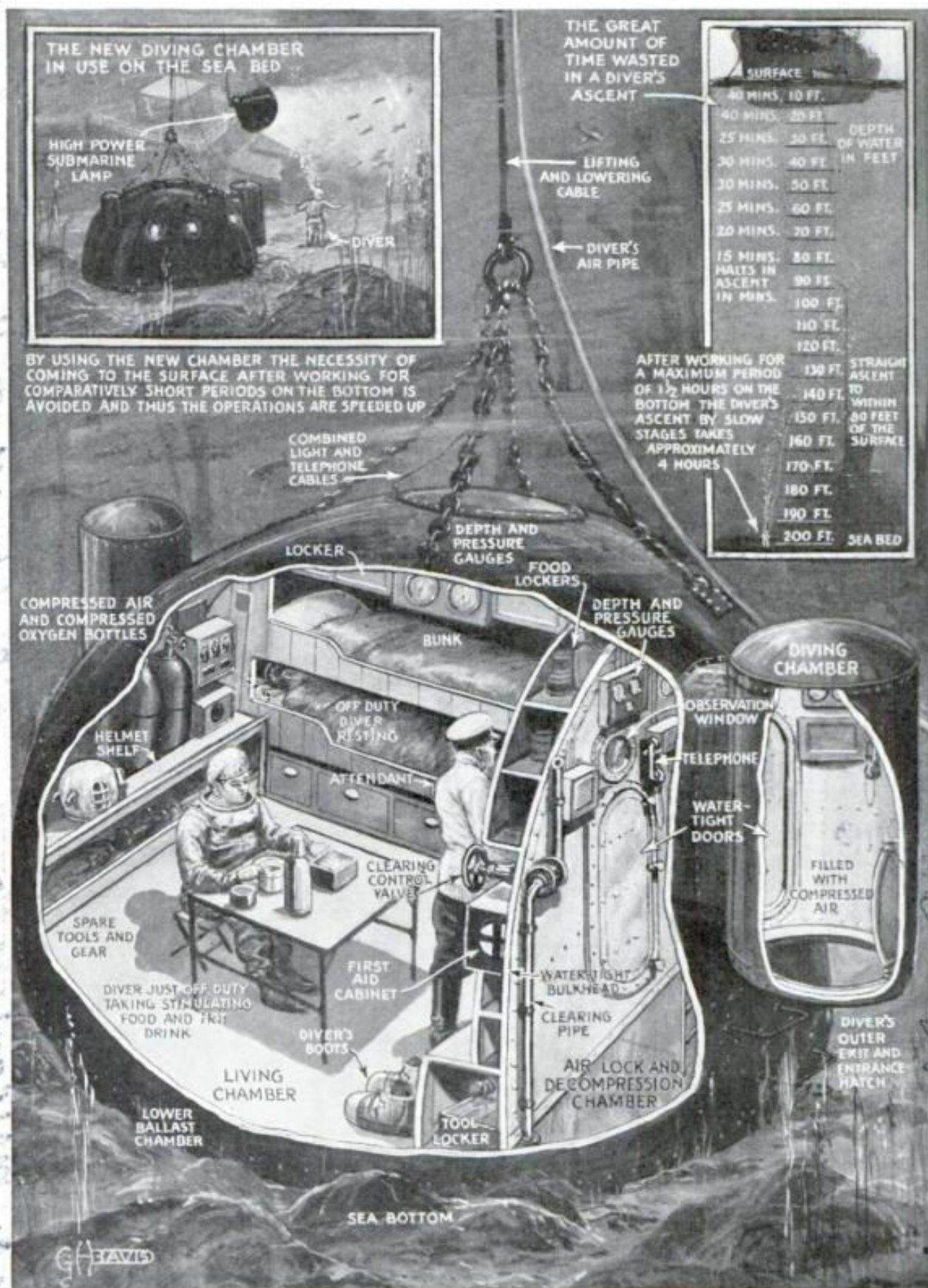
18 or the General Dynamics F-16. However, the critical components of both Soviet fighters appeared over-designed, so that close tolerances in manufacturing did not matter.

Rough and ready

Some accuse the Soviets of stressing quantity over quality, but they fail to consider the design philosophy behind planes such as the MiG-29 and Su-27. These fighters are designed for short-term combat reliability, rather than the Western goal of long-term durability in peacetime. Also, they are designed to be widely dispersed and rapidly employed, not tied to a fixed base. For example, both fighters have mechanisms built into their air intakes to keep them from ingesting debris from unpaved runways.

Cockpit instrumentation is one area where the Su-27 and MiG-29

Deep-Sea 'Home' for Divers Speeds Up Work



Designed to speed up operations and to prevent injury to divers through too rapid ascent, this submersible chamber serves as a home for diving crews working on the sea floor. This chamber may remain on bottom until work is completed.

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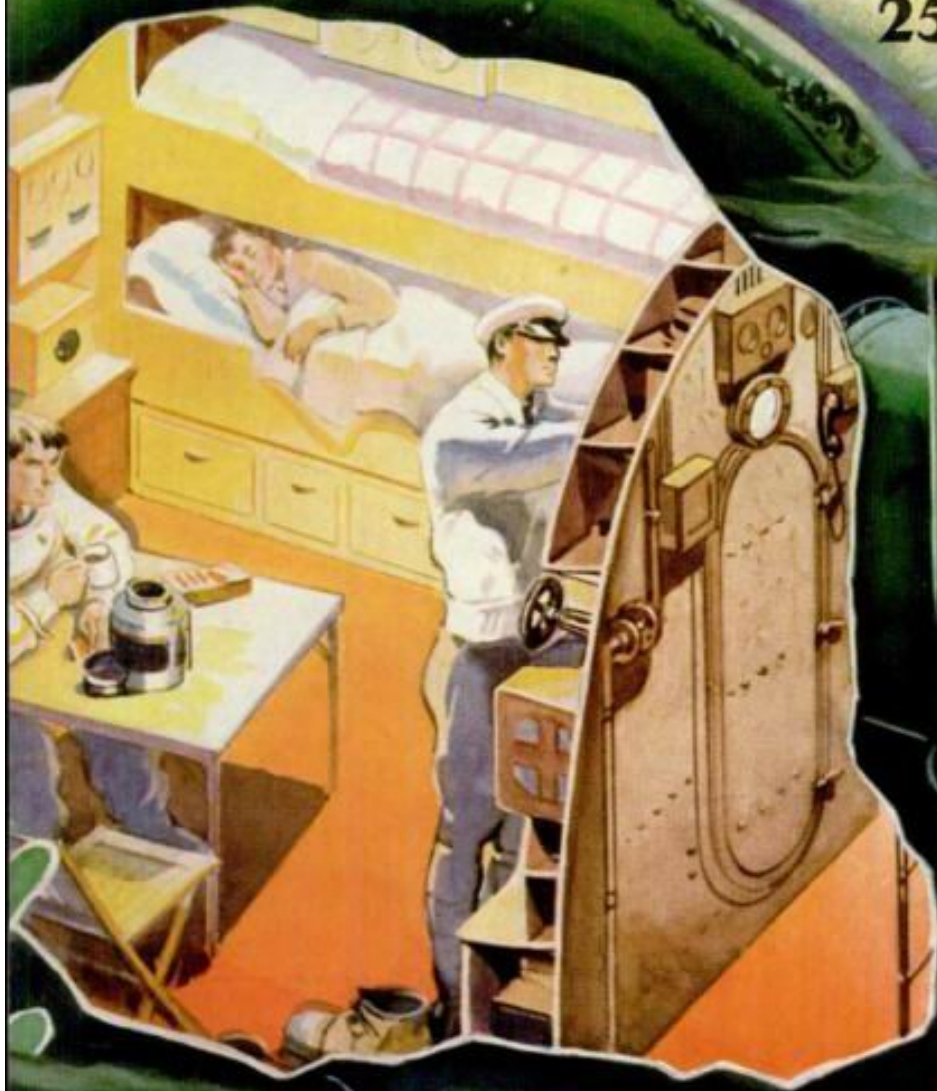
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MAZINE

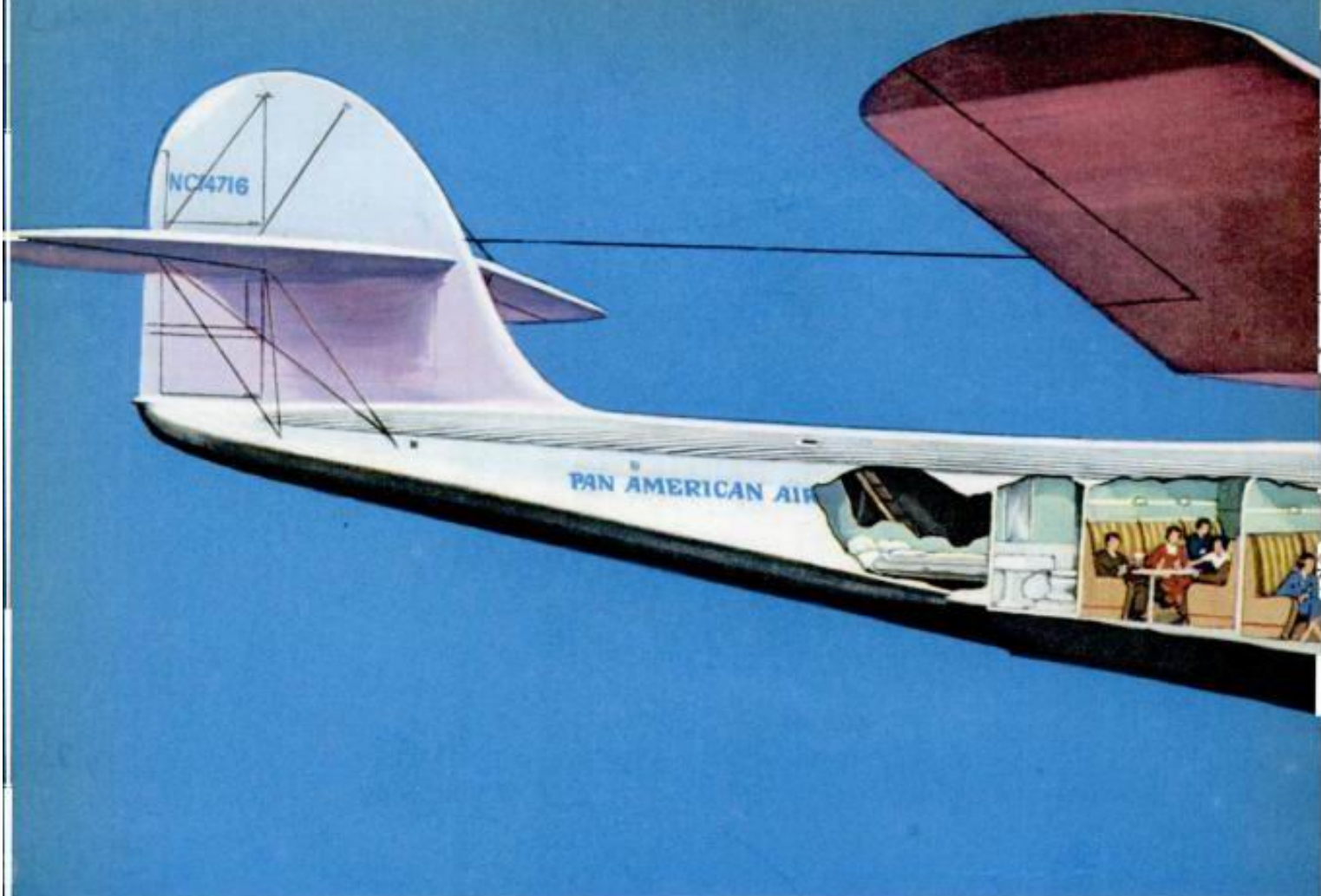
UNDERSTAND IT.



MARCH
25 CENTS



SEE PAGE 365



7263
332
the Pacific. The design and construction of the Clipper ships was an epic in itself. Pan American wanted seaworthy flying boats able to cruise 3,000 miles, even against a head wind, at 150 miles an hour. Also they must carry a profitable pay load. Igor Sikorsky built a nineteen-ton flying boat to fulfill trans-oceanic conditions and Glenn Martin built a twenty-five and one-half ton ship. Both planes emerged from flight tests with flying colors. The Brazilian Clipper, Sikorsky's ship, was licensed to carry 99.8 per cent of its own dead weight, the China Clipper produced by Martin, 102.1 per cent. Each had a top speed of more than 180 miles an hour and a cruising speed of 157 miles.

Next in importance were the island bases. Thousands of tons of supplies were taken to the little dots of land. Ground crews were left there to build everything from hotels to weather stations and air beacons. Then there was the matter of developing lightweight, low-powered radio to cover the whole Pacific and extending the range of air-

craft radio direction-finding devices. Crews were trained so that each man could perform the duties of every other member as well as his own. Test flights were made to prove the plans and everything went off like clockwork. Soon Clipper ships were making regular trips over the ocean—the Pacific had been conquered.

And now the Clippers are carrying passengers in five days over a route which the old sailing clippers required two months or more to travel. On your journey over the Pacific, you hop off from Manila, headed for Guam, 1,600 miles distant. The trip gives you ample opportunity to become acquainted with a modern air Clipper. Its two roomy compartments and main salon are equipped with comfortable divan seats. You can stroll about at leisure or, through the large windows, watch the clouds paint shadows on the water below. You see an occasional steamer plodding through the waves, rising and falling on the skyline. Tired of looking, you play cards, read, write, eat or sleep.



CROSS section drawing of China Clipper which has wing spread of 130 feet, length of ninety feet and a cruising speed of 150 miles an hour. T1263

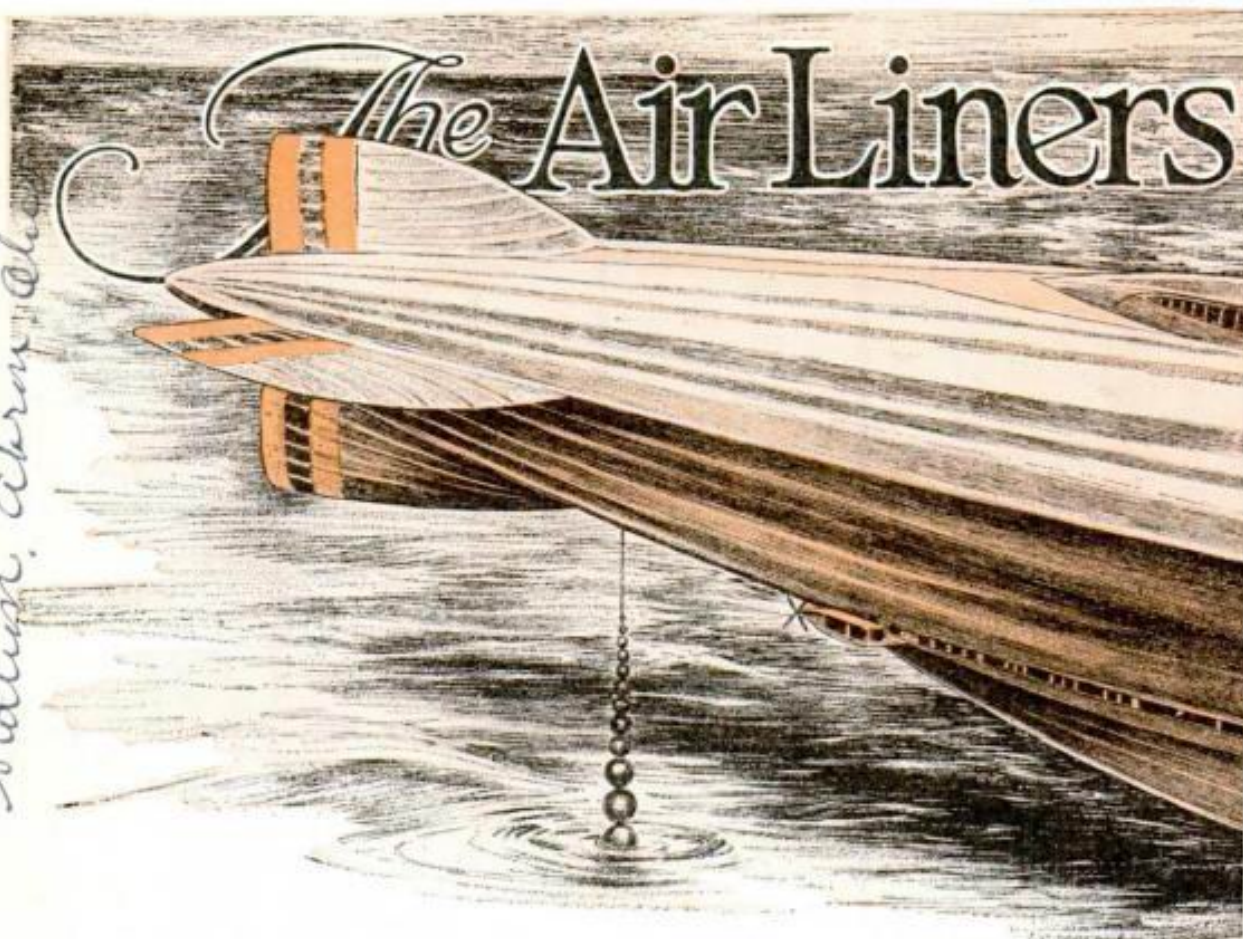
Up front the four twin-row 800-horsepower Wasp engines purr smoothly and on the flying bridge those of the crew of five on duty at the moment, are concerned with radio direction finding, navigation and maintaining radio contact with distant stations and steamers. At last your flying boat skirts a massive cliff rim and glides into the harbor at Guam. Perhaps you motor around the island, go to a movie or wander through the quaint old Spanish town. You spend the night at an Airway Inn—a hotel brought piecemeal to the island and set up in sections.

The next lap is from Guam to Wake, one of the longest of your flight. You are off at the crack of dawn and there's another day of watching the water. You'll find Wake a tiny mid-Pacific atoll consisting of three narrow islands, each about one and one-half miles long. Laid end to end, they form a horseshoe, the open end of which is protected by a massive reef to form a lagoon on which your

Clipper lands. Here you find a little village—a dozen houses, a big beacon, an Airway Inn, a dock. You may fish or dive down into the magnificent forest of coral, wearing water glasses so you can get a closeup view of the multi-colored tropical fish.

Another dawn and you're on your way to Midway, 1,300 miles east. On this leg you cross the international date line and lose track of time. If you left Wake Friday morning, you'll land at Midway Thursday evening. Midway consists of two small islands surrounded by a coral reef. On the larger is a cable station which, until the arrival of Pan American, was the only form of habitation. Now there's a hotel with dining rooms, lounges, porches and showers to accommodate forty-eight passengers. Here is a miniature forest of Australian pines, the result of thirty years of effort by cable company employes. Here also, ironically, are three graves of three doctors who, in the course of a quarter

3905
Capt. Walter E. Burton, 1922
Alpanda Ave. Keenmore
Station, Akron, Ohio



Artist's Conception of How Air Liner of the Future Might Be Anchored off Shore on a Special Landing Buoy in Regions Where Construction of Hangars Is Impractical

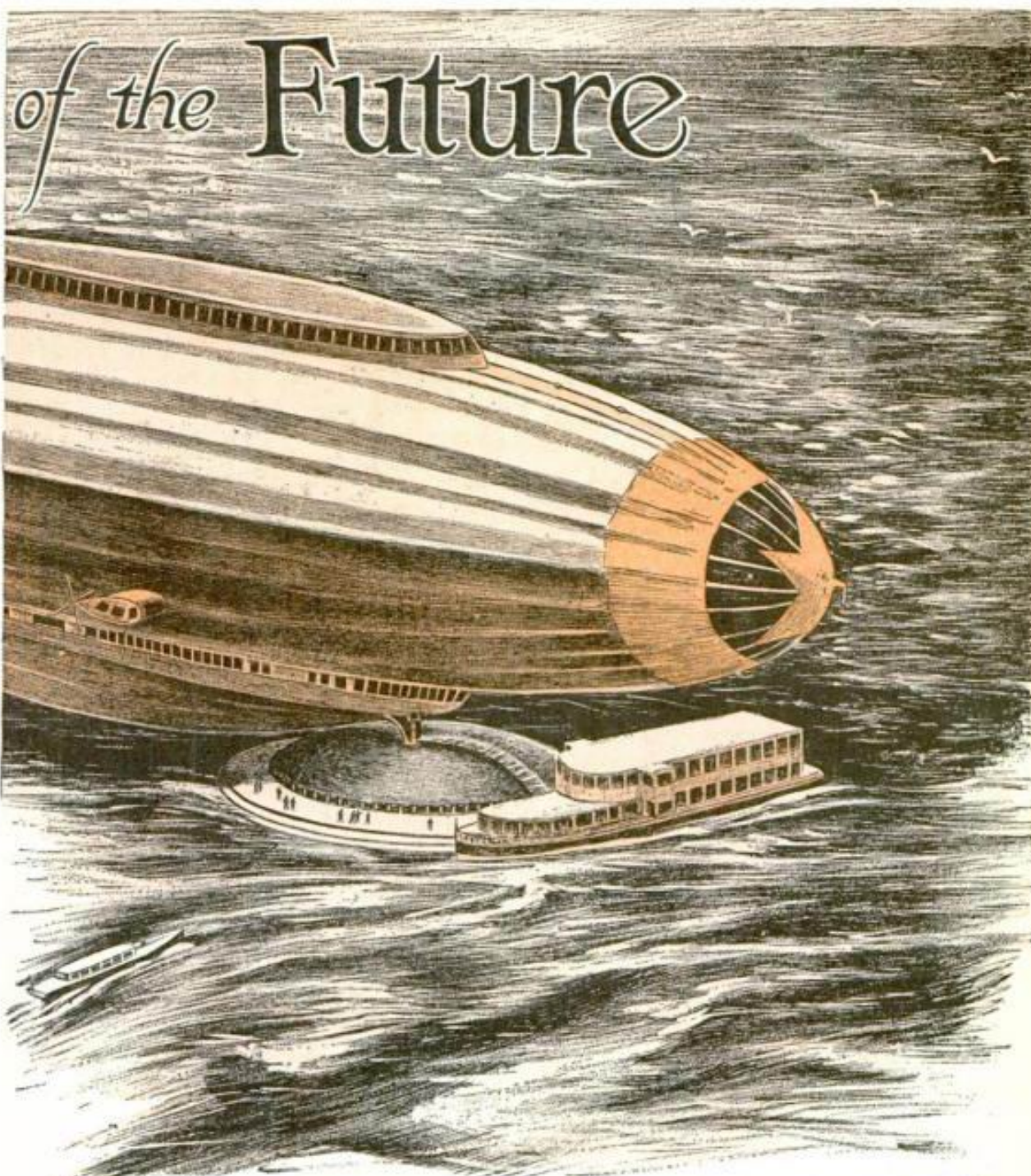
By JOHN DRAPER

THE DREAM of inventors who pictured the day when huge air liners that would bring Podunk within a few hours of Paris, seems about to be realized. Count Ferdinand von Zeppelin flew his first successful rigid airship in July, 1900, over Lake Constance on the German-Swiss border. Since then, there has been rapid development of this mode of travel. The World War helped tremendously, but it is only within the past year or two that the Zeppelin has become a transportation factor. The "Graf's" world trip was a realization of Count Zeppelin's dream wherein he saw all countries of the earth linked by huge swift-flying air liners.

The voyages of the "Graf" demonstrated many things about airship navigation over long distances. That there is need for better methods of obtaining reliable weather reports is one of the most outstanding. Throughout the twenty-one-day world journey, Dr. Hugo Eckener had to rely largely on his own experience

and perception of conditions to determine the best courses. He received weather reports over Europe, America and the oceans, but this information was almost entirely lacking over Asia and left much to be desired at other points. Undoubtedly, when airship travel becomes an everyday matter, there will be a well-organized network of weather stations, radio transmitters, and like equipment, covering the earth. Then the condition of the weather will have only a limited effect on airship-line operation.

Builders of the "Graf Zeppelin" had to make it to fit the only large hangar available in Germany. Therefore the ship is not of ideal proportions. Its steering mechanism is not entirely satisfactory, and its speed is too low. Doctor Eckener, following the world trip, declared that future long-distance airships ought to be fatter—have a lower ratio between length and diameter—than the "Graf." They also must be more powerful if they are to

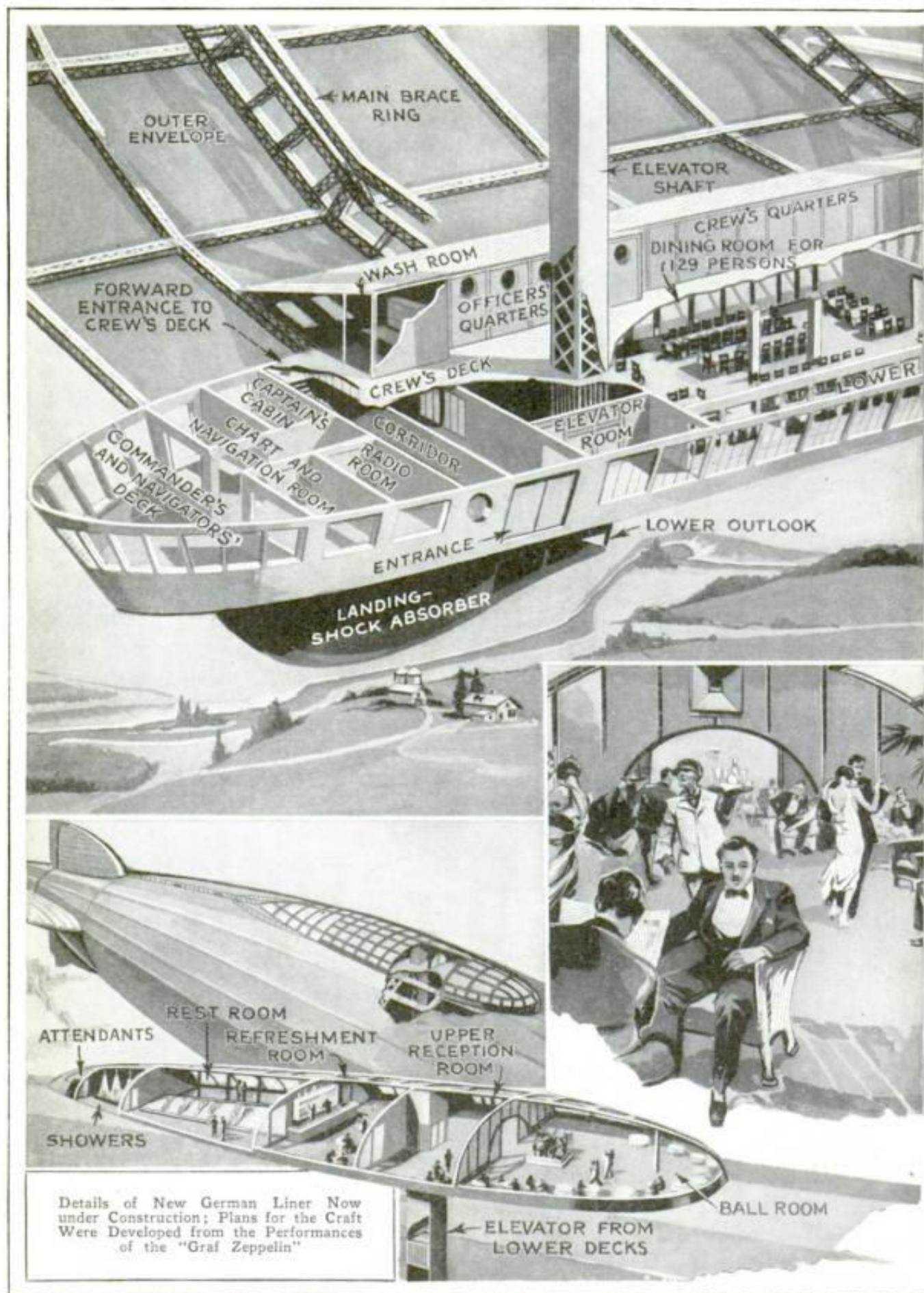


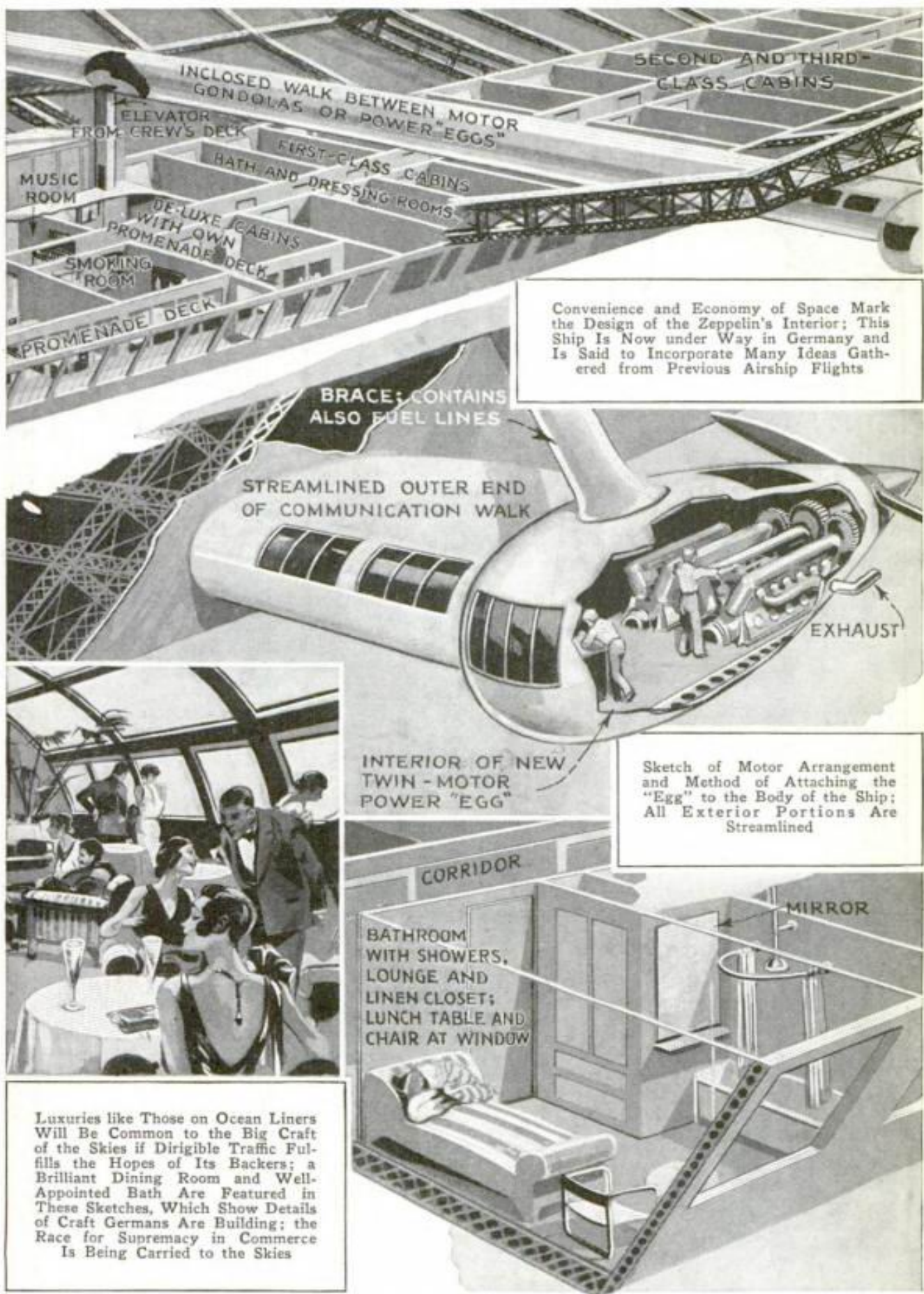
The "Landing Foot" of the Craft Slips into Slot of Buoy While Globelike Buckets That Fill with Water Are Lowered from the Rear to Serve as Anchors

maintain reliable schedules regardless of weather. The "Graf" also suffered from a kind of skin affliction. That is, its fabric covering became loosened in several places during a long flight. This was remedied by installing light reefing frames. In future ships, adjustable bars will be provided so that the fabric can be loosened or tightened as desired.

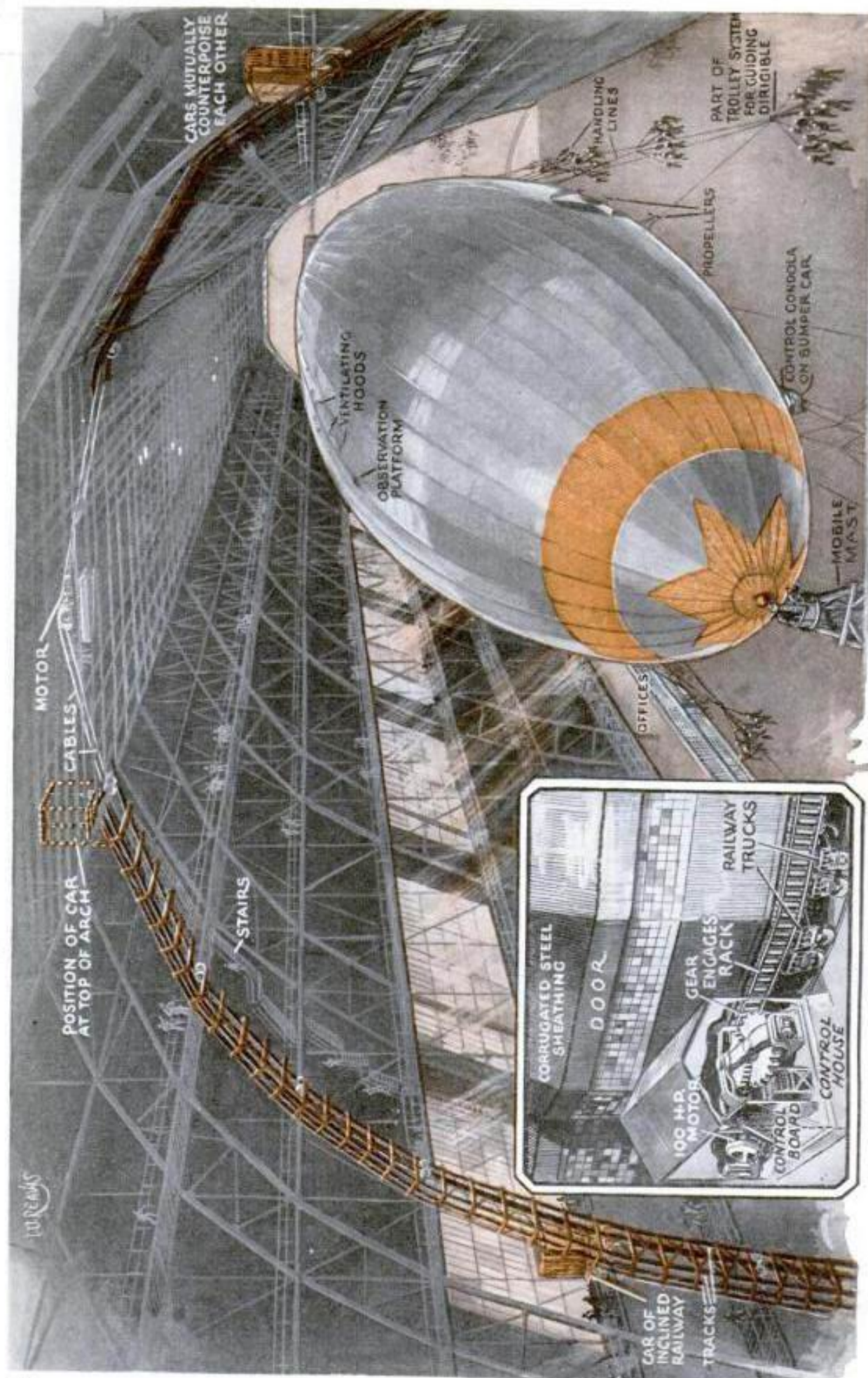
Many improvements which the "Graf" lacked are being embodied in the new German dirigible now under construction

at Friedrichshafen, the two British ships "R-100" and "R-101," and the United States navy airships "ZRS-4" and "ZRS-5," now being built at Akron, Ohio, by the Goodyear-Zeppelin corporation. The new German dirigible is thirty per cent larger than the "Graf"; has eight motors instead of five, and retains the outside motor gondolas because inflammable hydrogen gas will be used for lift. It will be completed in the spring of 1931. The "R-101," recently flown, is shorter than





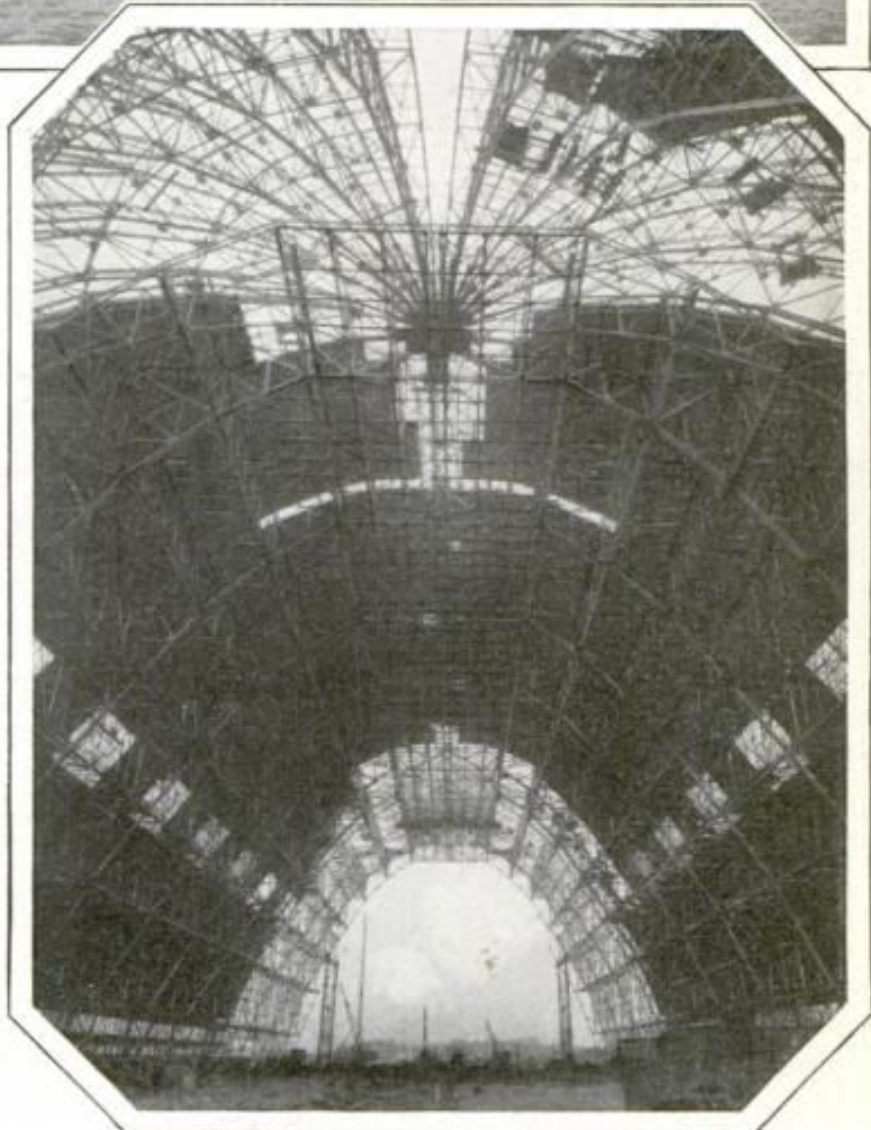
3705



How Craft May Be Brought into the Dock of the Goodyear-Zeppelin Corporation at Akron, Ohio, and a Close View of the Operating Mechanism of the "Orange Peel" Doors; the First of Two Dirigibles for the Navy Is Now under Construction in This Huge Dock Which Was Completed Recently



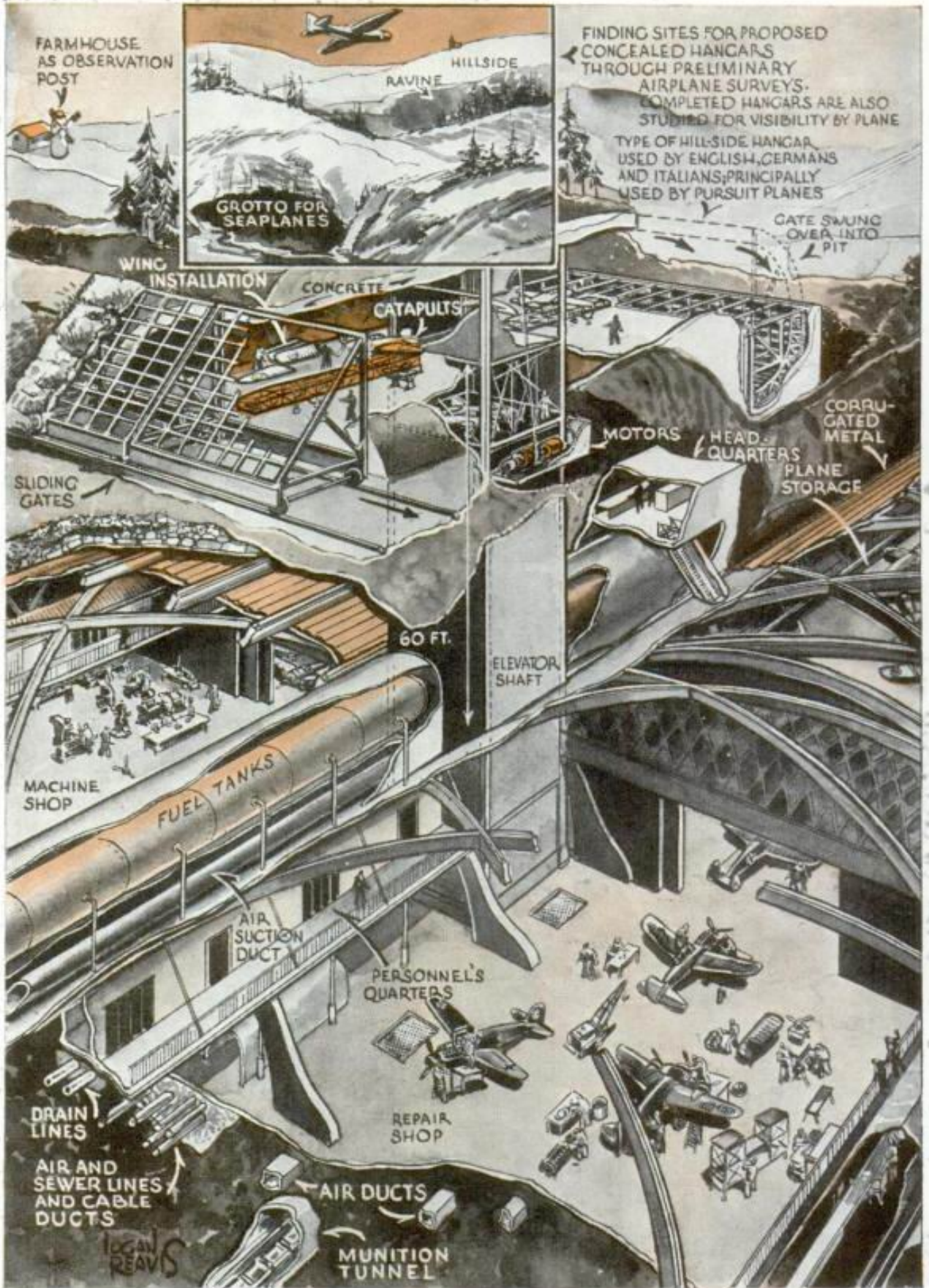
the "Graf" but is fatter and therefore has a greater useful load. It departs from previous practice by using stainless-steel girders. Both the British and German ships hold approximately 5,000,000 cubic feet of hydrogen. The two new American ships are larger, being of 6,500,000-cubic-foot capacity, but the lift produced by the helium they will use will be about equal to that of a 5,000,000-cubic-foot hydrogen ship. Because helium will not burn, these ships will represent many innovations in design. Almost everything will be inside the hull, where wind resistance is nil. The propellers and their outriggers, control surfaces and control room will be practically the only protruding parts. Motor rooms, being inside the framework, can be larger and of stronger construction. Passenger and crew quarters will be more extensive than in any previous airship. Each ship will have three triangular keels. Corridors, staterooms and other compartments will be located inside these keels.



Composite Photo-Diagram to Show Size of the Dirigible Dock, and View of Interior When Structure Was about Three-Fourths Finished

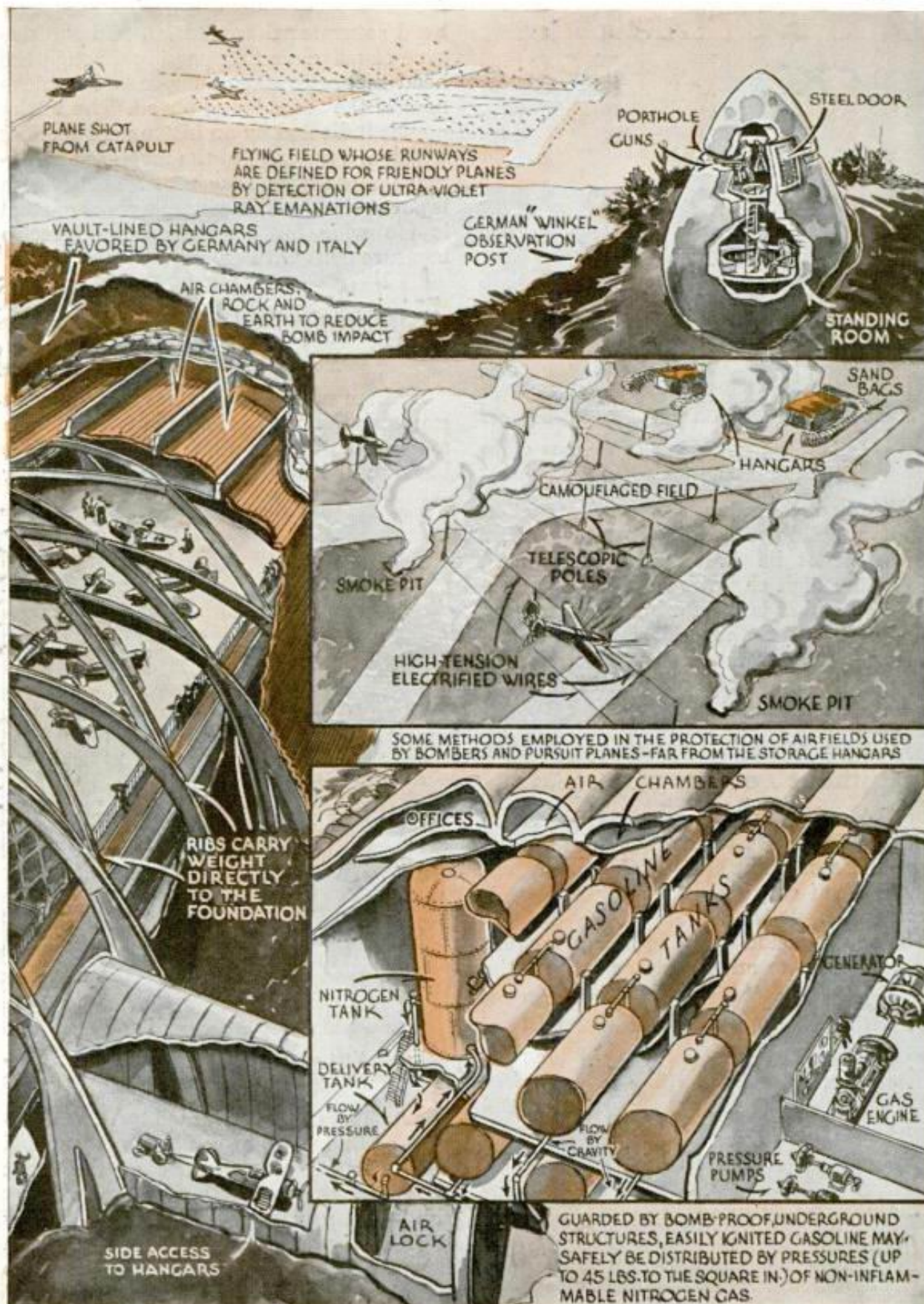
Perhaps the most spectacular phase of the airship's growth is its recently acquired ability to carry airplanes. The new British ships, it is reported, are designed primarily as motherships for air-

Warplanes Hide in Vaults Deep Under Hill



Deep down in the wooded hillsides of Germany, Italy and Britain are vast hangars where warplanes can be stored and repaired, safe from observation and bombs. These drawings were made from actual designs of an American engineer, C. G. Flebus, who was engaged by the axis governments on the subterranean vaults. Disappearing gates hide exits from which catapults shoot planes

Pressure Tanks Feed Fuel to Buried Hangar



Landing fields for the bombers and fighters are well camouflaged and guarded from enemy planes by telescoping poles and high-tension wires as well as concealed gun nests. Near the bombproof vaults and the seaside grottos where seaplanes hide are huge underground storage tanks from which gasoline is fed into the hangars by the force of compressed, noninflammable nitrogen gas.